003 Marshall

N64 27268

code 1
NASA CR 55847
cat. 15

78 p.

PERKIN-ELMER

OTS PRICE

XEROX $ 7.60 ph

MICROFILM $ ________

SPT-10542

PERKIN-ELMER

ELECTRO-OPTICAL DIVISION NORWALK, CONNECTICUT

ENGINEERING REPORT NO. 7030B

SATURN LONG RANGE AZIMUTH ALIGNMENT THEODOLITE (LR2A)

DATE: May 6, 1963

PREPARED FOR: GEORGE C. MARSHALL SPACE FLIGHT CENTER

NATIONAL AERONAUTICS AND SPACE AGENCY

HUNTSVILLE, ALABAMA

J.R. Vyce

[illegible]

Contributors:

W. Kokot
W. Zukowsky

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

PREFACE

This document constitutes the final engineering report for contract number NAS 8-2555, George C. Marshall Space Flight Center, National Aeronautics and Space Administration.

The report is similar to Perkin-Elmer preliminary report No. 7030A (previously submitted to NASA) and incorporates a description of all refinements made to the LR2A instrument to date.

Sections IV, V, and VI have been added to include the actual test procedure followed, test results, future modifications, and a summary.

Section IIIA has been revised to include the effects of the sensing prism re-imaging technique incorporated into the instrument.

Section IIIC has also been revised to include a reference prism modification and a new gain adjustment scheme.

All other deviations from report No. 7030A are minor and in no way effect the stated conclusions.

SECTION I

INTRODUCTION

The azimuth alignment theodolite required for the various Saturn vehicles will operate at distances of from 300 to 1000 feet at elevation angles to 40 degrees. It must measure azimuth deviation angles of up to ±1 minute with 5 second accuracy in the presence of ±3 inches of dynamic vehicle sway and ±12 inches of long term deflection.

The instrument consists of an 8-inch aperture automatic null-sensing autocollimator whose line of sight is directed through a movable penta mirror to the 2 x 2-inch Saturn inertial reference platform prism. Dynamic sway compensation is provided by the 8-inch aperture, while penta translation provides errorless compensation for the larger long term deflection.

SECTION II

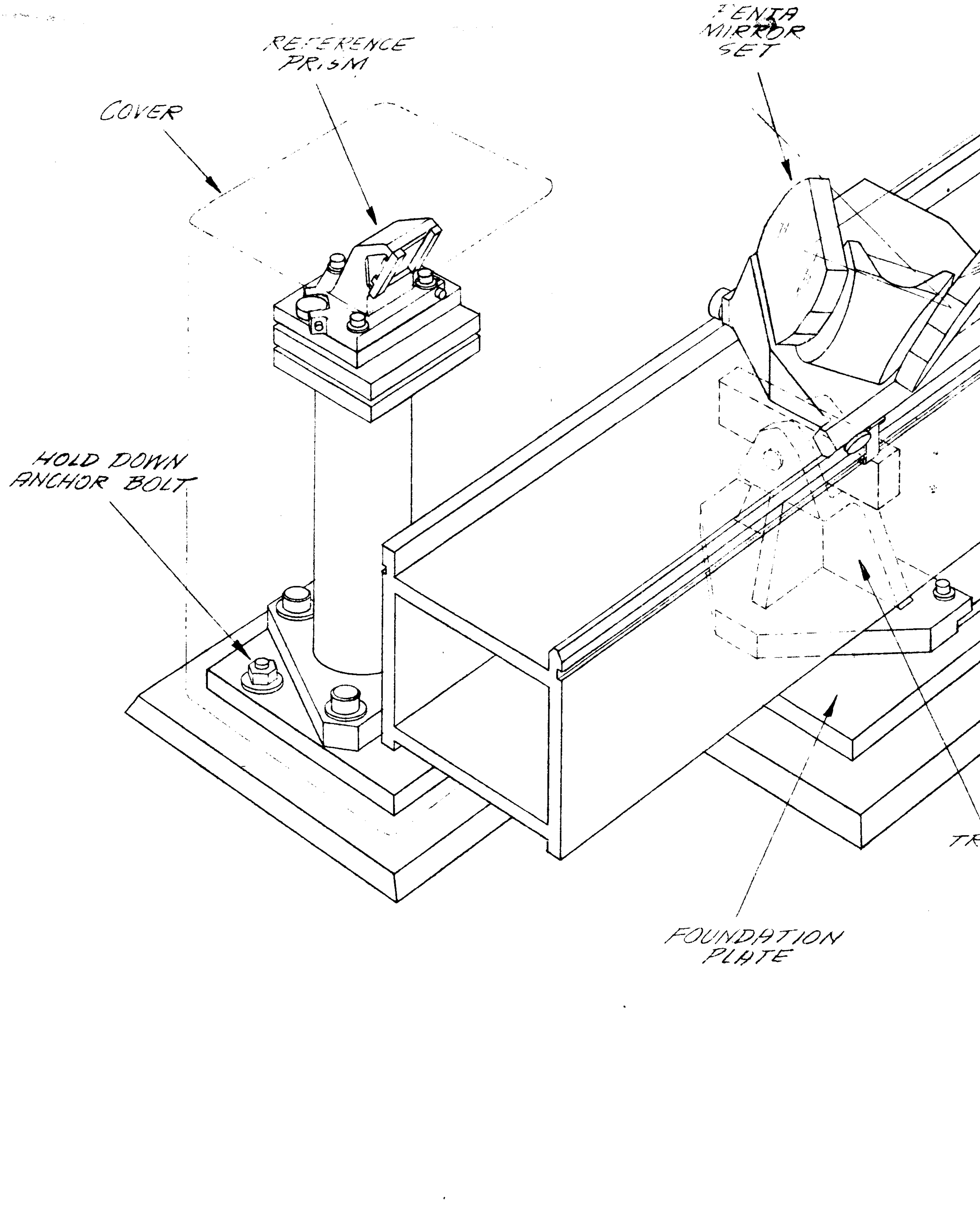
GENERAL DESCRIPTION OF THE EQUIPMENT

A. THE OVERALL SYSTEM

The general form of the long range theodolite to be supplied (designated as LR2A) is shown in Figure 1, the autocollimator optical arrangement in Figure 2, the functional block diagram in Figure 3, and the alignment arrangement in Figure 4.

The autocollimator and the translating penta mirror are on a lathe-bed type base which may be elevated during setup to acquire the inertial platform reference prism. The penta deviates the autocollimator beam to the 2 x 2-inch prism, and the energy reflected back to the autocollimator generates an error signal whenever the prism moves from the desired azimuth orientation. The vehicle can be seen at all times in the TV camera (supplied by NASA) which views through the autocollimator, and the penta may be remotely controlled to maintain the platform prism centered in the field. Penta deviation is unaffected by small rotations, and thus the alignment direction is unchanged as the prism translates.

The 8-inch autocollimator aperture provides ±3 inches of dynamic sway compensation when the platform prism is nulled, and therefore the penta need not be positioned with especially great accuracy. A fixed reference prism is located within the range of penta travel and oriented normal to the desired alignment direction by survey. Autocollimator zero alignment can easily be


REFERENCE PRISM
COVER
MIRROR SET
HOLD DOWN ANCHOR BOLT
FOUNDATION PLATE

REPORT NO. 7030A
REPORT NO. 7228
REPORT NO. 7030B

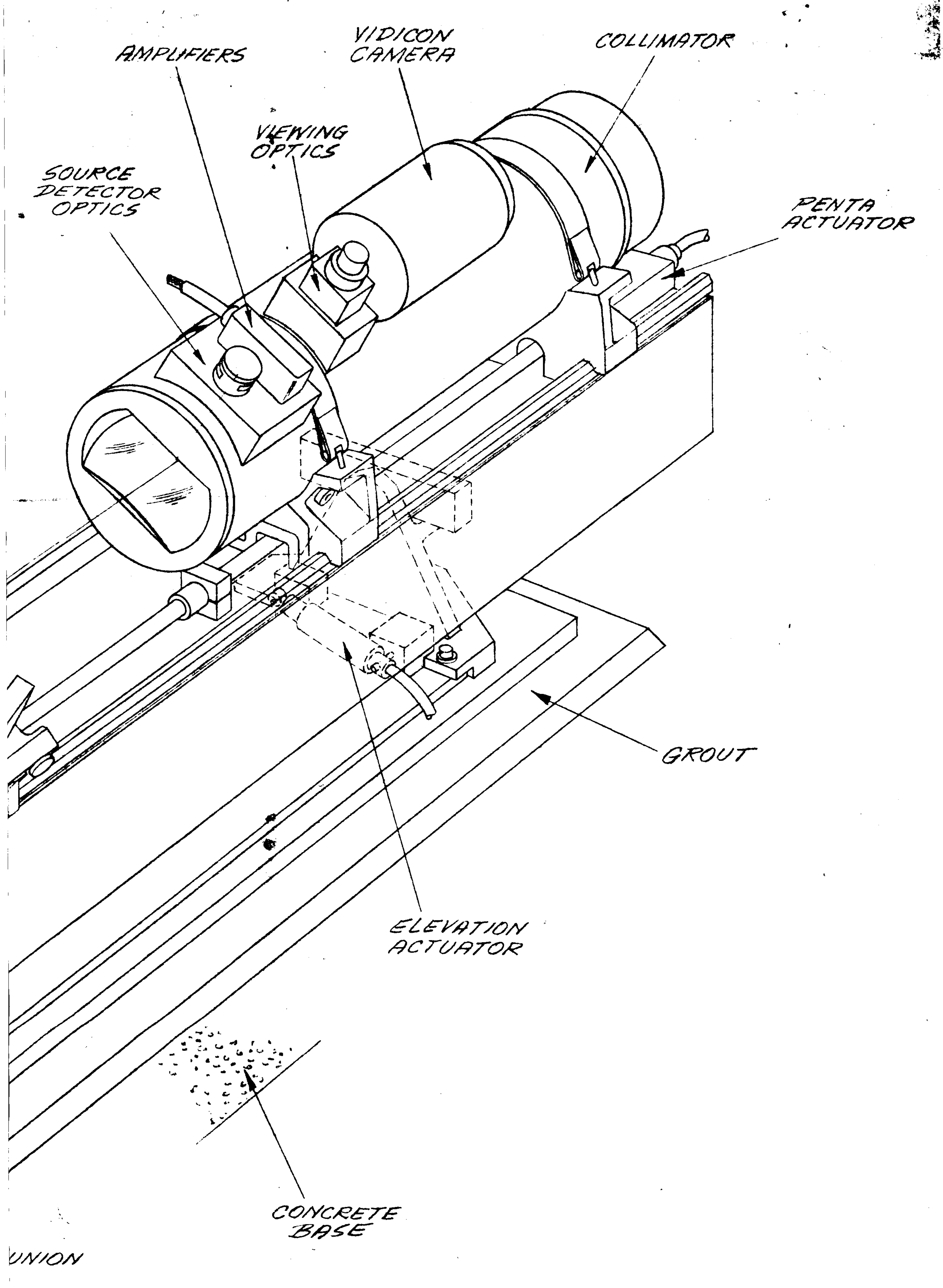


FIGURE 1

SYSTEM LAYOUT, SATURN THEODOLITE

SK 111C6794

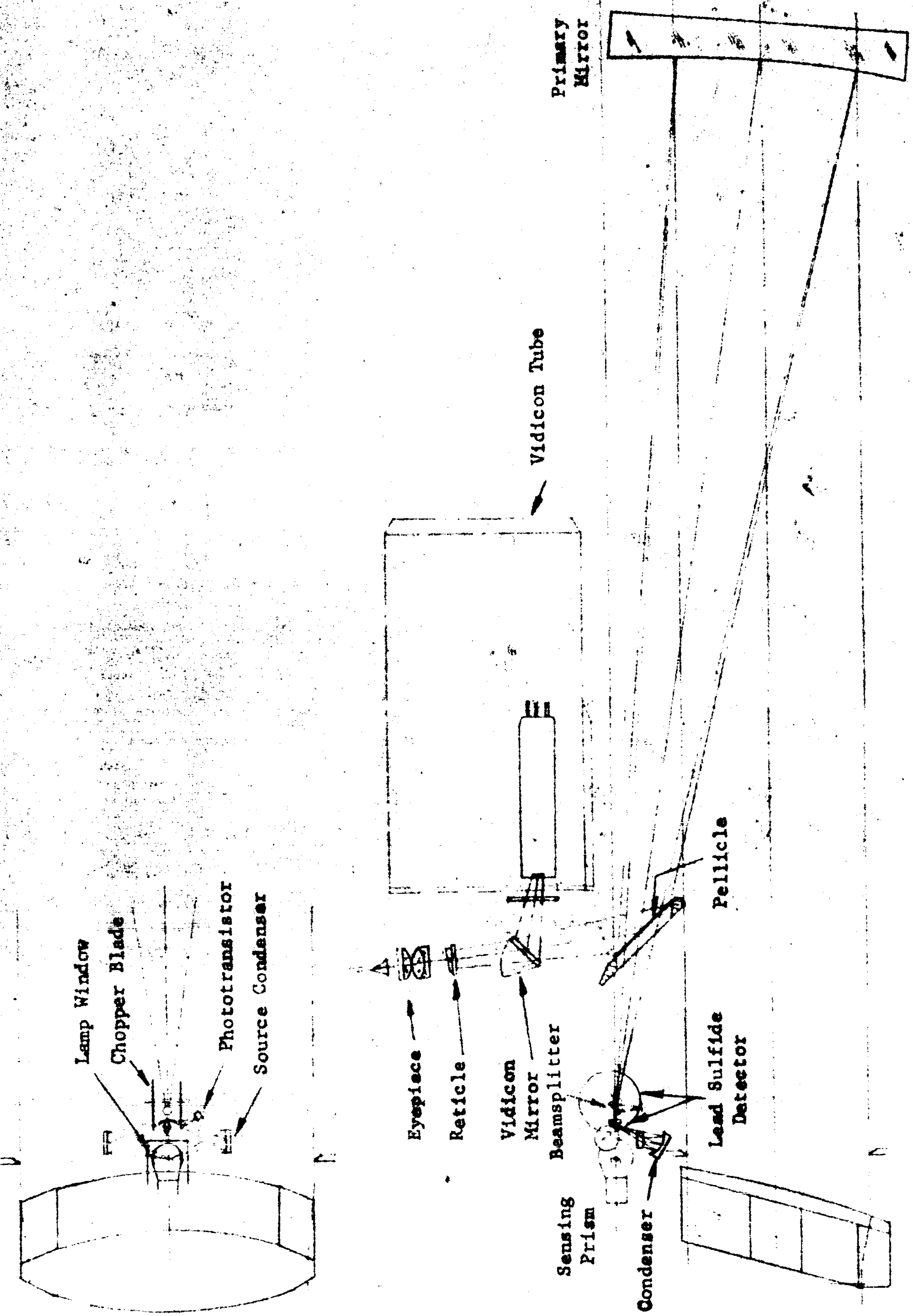
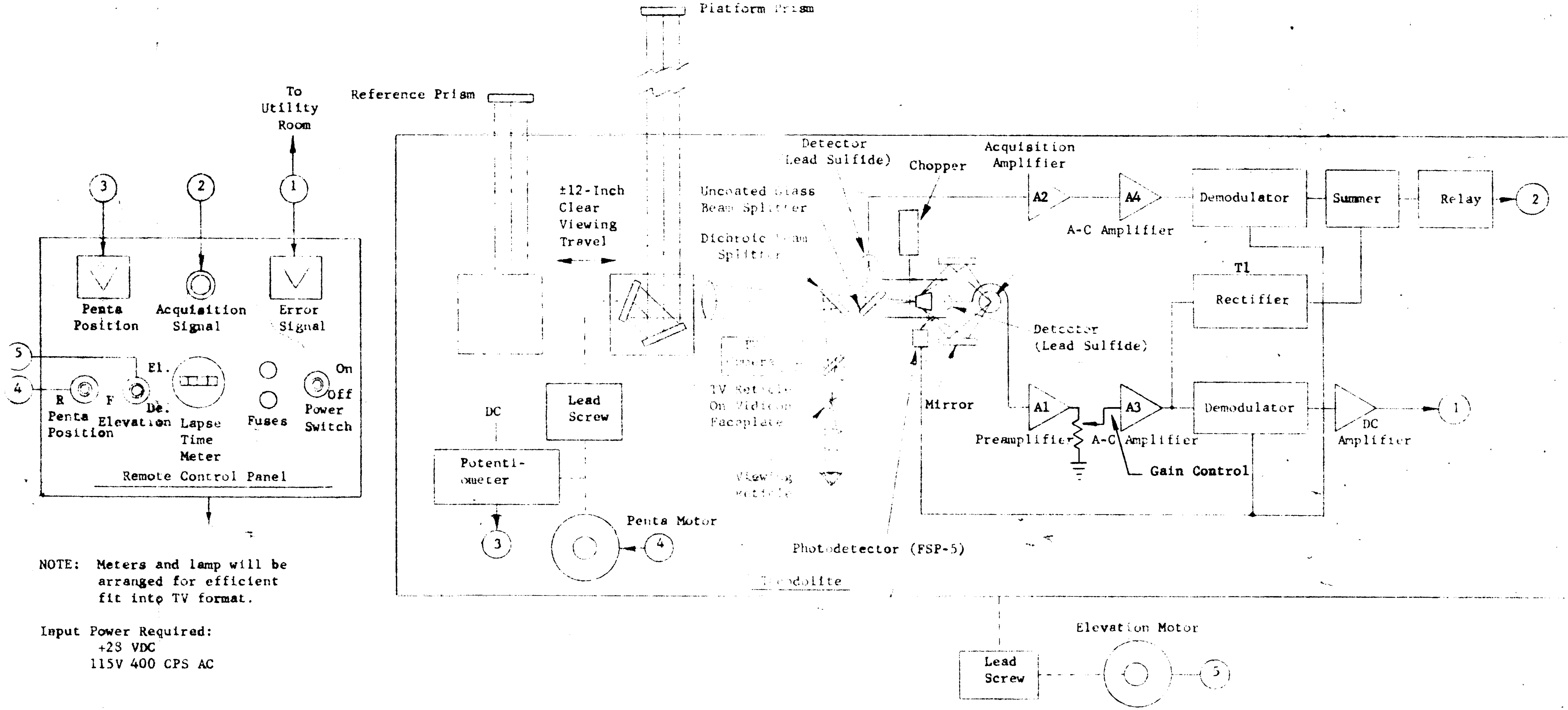


Figure 2. Autocollimator Optical Arrangement



NOTE: Meters and lamp will be arranged for efficient fit into TV format.

Input Power Required:
+28 VDC
115V 400 CPS AC

Figure 3. Functional Block Diagram - Saturn Theodolite (L62A)

SK111B 6793-A

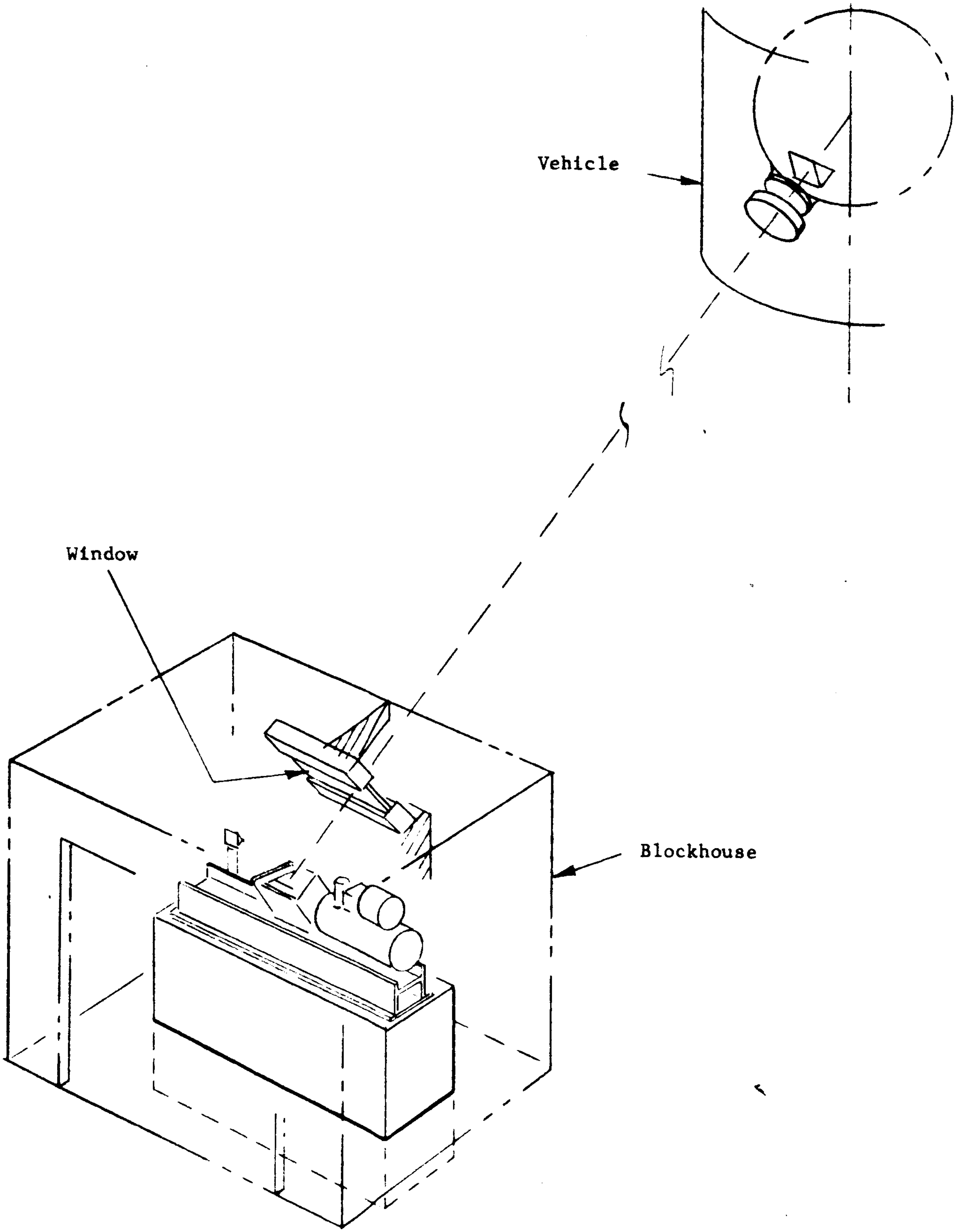


Figure 4. Alignment Arrangement

checked by autocollimation with the reference prism when the penta is positioned in front of it. Any error observed may be corrected:

(1) by operator azimuth adjustment of the instrument; and

(2) by remote compensation of the guidance system (not part of the LR2A equipment).

The indicators and the controls are in a rack mounted package located in the theodolite hut and permit convenient setup, acquisition, and monitoring. The indicators are two voltmeters and a lamp, and the controls are switches. A NASA TV camera will view the indicators for remote viewing, and the controls are operated through D-C relays which allow parallel remote operation. It is evident that the LR2A constitutes a simple, effective, and highly accurate solution to the Saturn azimuth alignment problem.

B. THE AUTOCOLLIMATOR

The autocollimator consists of an 8-inch off-axis Maksutov catadioptric lens of about 30 inch focal length with automatic, TV, and visual sensing means at its focus. The automatic sensing equipment has the same form as that used in almost all of the many Perkin-Elmer alignment instruments. Light from an incandescent lamp, made alternately incident or either side of the slit prism nose by a motor driven chopper, is reflected to the objective lens, collimated, transmitted to the platform prism, and reflected back to the objective which reimages the illuminated slit in its own plane at unity magnification. If the platform prism is not precisely normal to the autocollimator axis, the returned image will be displaced laterally on the slit and light of one phase will be incident on the lead sulfide (PbS) detector located below. The magnitude of the signal is proportional to the prism deviation from null, and the signal phase indicates the direction of deviation.

The configuration of the source condenser mirrors and sensing prism is such that some light incident on the nose of the prism would spillover into the error detector if it were located directly behind the prism. To avoid the adverse effects of this spillover light a re-imaging system is located behind the prism which serves to image the clear nose of the sensing prism on a mechanical slit. This slit is made narrow enough to exclude all spillover light yet it is wide enough to include all error signal energy. The net result is a clean error signal free of residual spillover signal.

Chopping phase is sensed by a detector which provides the reference signal required for error signal demodulation. The autocollimator supplies a DC output signal which remotely modulates the inertial platform 400 cps carrier, thereby avoiding transmission of that carrier to the theodolite hut. The autocollimator error signal reduces essentially to zero at autocollimator null, where the first harmonic signal also has a very low level. The measuring detector consequently does not contain sufficiently positive acquisition information near null. A separate acquisition detector is therefore employed which sees a large part of the autocollimated light source image and provides a positive acquisition signal in the form of a relay closure and an illuminated lamp. The autocollimator is completely static during monitoring except for the internal chopper. It is required to move in elevation with the penta during setup primarily to prevent the collimated slit from rotating out of vertical, as it would otherwise do.

The TV camera normally looks through the autocollimator, but a selector mirror permits direct viewing through a focusing eyepiece which permits alignment of the instrument during setup.

C. THE TRANSLATION MECHANISM

The most important design feature of the LR2A is the use of a movable penta mirror to provide: initial positioning of the line of sight, large amplitude sway compensation, and convenient access to the reference prism.

The penta mirror is a constant deviation device which permits translating the transmitted beam precisely parallel to itself in the presence of small penta angular disturbances. Penta angular motion of more than 4 arc minutes must occur before the transmitted beam will shift more than 1 second. Thus, there is no great difficulty in providing a penta track sufficiently flat and straight to insure that less than 1 second of shift occurs during penta translation. Since the shift is given by the square of penta angular motion, it decreases rapidly as this angular motion is reduced below 4 minutes.

The three functions accomplished by penta translation are effected by manual control of penta position. Initial positioning and sway compensation adjustments are made in accordance with the view seen by the autocollimated TV camera. Translation of the penta in front of the reference prism is evidenced by a darkening of the TV view and by a position indication on the penta position meter.

The penta is driven over a travel of 30 inches by a ball-bearing lead screw actuator operated by a DC motor. A built-in potentiometer permits position readout on a suitably enscribed meter.

D. THE ELEVATION MECHANISM

The elevation mechanism permits convenient local or remote elevation adjustment of the LR2A base during setup over a range from 20 degrees to 40 degrees, with a nominal operating value of 30 degrees. The elevation angle will not be changed during operation.

There are several ways in which the elevation axis may be located with respect to the reference prism to insure that the transmitted beam is incident on that prism at any elevation angle. Because the LR2A will be normally used over only a small part of its elevation range, its design is simplified by use of the elevation mechanism illustrated in Figure 1. The reference prism is provided with a height adjustment to accommodate gross changes in monitoring elevation angle.

The elevation adjustment will be made through a DC motor-driven ball-bearing lead screw actuator in accordance with the view transmitted by the TV camera.

E. THE REFERENCE PRISM

The reference prism is a roof prism aligned with its apex horizontal and oriented normal to the desired azimuth direction of platform prism alignment. It is located at the end of penta travel, and may be viewed whenever it is desired to check autocollimator null alignment.

The prism has one end mirrored and normal to the apex in a vertical plane to permit convenient levelling of the apex with an optical level or theodolite. Its azimuth orientation must be established by a first order survey.

The prism mounting is made extremely rigid and stable to reliably maintain reference orientation. Its height may be adjusted as discussed above.

F. THE CONTROL PANEL

Associated with the LR2A is a control panel (see Figure) which incorporates the indicators and controls required for operation. The indicators are two appropriately enscribed 7 inch meters which measure voltages representing the following:

(1) Penta position

(2) Azimuth error angle; and

(3) A lamp, which when on indicates that the instrument is autocollimated with the platform prism.

NASA will provide separately the very important additional indictors for remote checking of LR2A operation:

(1) The TV picture of the view through the LR2A

(2) The TV picture of the control panel

The controls for the LR2A consist of:

(1) Penta position

(2) Elevation

Control of these functions is effected by two panel switches through DC relays. The relays may also be operated from a remote location if suitable DC signals are introduced in parallel with the switch inputs.

G. SYSTEM INSTALLATION AND ALIGNMENT

The LR2A will be installed on a very massive and stable concrete base in an air conditioned hut (see Figure 4) which protects it from precipitation, condensation, large temperature variation, and blowing sand, mist, etc.

The high quality hut window through which monitoring will take place is to be supplied by PECO, and will be discussed in greater detail further along in this report.

The present alignment concept is as follows. The reference prism and LR2A are installed, levelled, and aligned roughly. The autocollimator is energized and with the penta in the center of its travel the LR2A is adjusted in azimuth and elevation until the reticle crosswires are centered on the missile window. The penta is then moved in front of the reference prism and the latter adjusted in azimuth until the autocollimator is nulled. By a first order survey the azimuth of the reference prism, and therefore of the alignment direction, is determined.

After setup, there should be little change in LR2A azimuth orientation. In the unlikely event that a null shift should occur it will be denoted by the present of an azimuth error signal on the control panel when the instrument is checked with the reference prism. Small null shifts presumably can be compensated within the NASA control loop from the blockhouse.

H. SYSTEMS OPERATION

At any time after alignment the following operating procedure will be employed.

The penta is set in the center of its travel and the elevation angle adjusted to the value for the given operating distance and platform prism height. While observing the TV picture or looking through the eyepiece, both elevation and penta position are adjusted to direct the LR2A beam to the platform prism.

The penta is then moved to the checking position in front of the reference prism, and the LR2A output signal observed. It may either be corrected by adjustment of the LR2A or compensated in the control loop. The penta is again moved back to view the platform prism, and the platform is torqued in azimuth toward the alignment line of sight. Acquisition of the prism will be observed by illumination of the acquisition lamp and the appearance of a signal on the azimuth error meter. The LR2A output signal may then be used to maintain the platform fixed in the alignment azimuth.

It is to be reiterated that by appropriate connections to the LR2A the complete operational procedure may be performed from the blockhouse.

SECTION III

SYSTEM ANALYSIS AND DETAILED DESCRIPTION

A. AUTOCOLLIMATOR ELECTRO-OPTICAL PERFORMANCE

1. General Procedure

The first step in predicting autocollimator performance is to compute its radiant sensitivity, or the energy which becomes incident on its detector for a given mirror deviation angle. For an azimuth autocollimator with a small proportional range (slit angle small with respect to angle subtended by objective lens at mirror), this is accomplished by:

(1) computing the integrated energy per unit width in the autocollimated image of a lossless system along a vertical on-axis line, and

(2) taking its product with the amount of horizontal image motion corresponding to the desired mirror deviation angle.

This basic result is then reduced by a gain factor made up of several terms (due to absorption, reflection, filament geometry, etc.) which gives the useful signal at the detector. The autocollimator signal-to-noise ratio (SNR) follows by relating the modulated signal to the detector noise characteristics, and limiting autocollimator performance may be inferred directly therefrom.

2. Basic Transmission

Along the vertical line image in Figure 5 any axial infinitesimal point of area A contains energy

$$\Delta P = N \frac{a^2}{f^2} \Delta A$$

where N = source radiance = $\frac{350 \text{ Watts}}{\pi \text{ in.}^2 \text{ steradian}}$ for a 2400°K source with emissivity of .296. For off-axis points the image irradiance decreases due to vignetting as in Figure 5, from which the vignetting coefficient is seen to be

$$\overline{Kv} = 0.8$$

for a = 2 inches, b = 5 inches; and the image height is

$$h = \frac{bf}{D}$$

The image energy per unit width Δw, where $\Delta A = h\Delta w = \frac{bf}{D} \Delta w$ is

$$\frac{\Delta P}{\Delta w} = \left(N \frac{a^2}{f^2}\right)\left(\overline{Kv} \frac{bf}{D}\right)$$

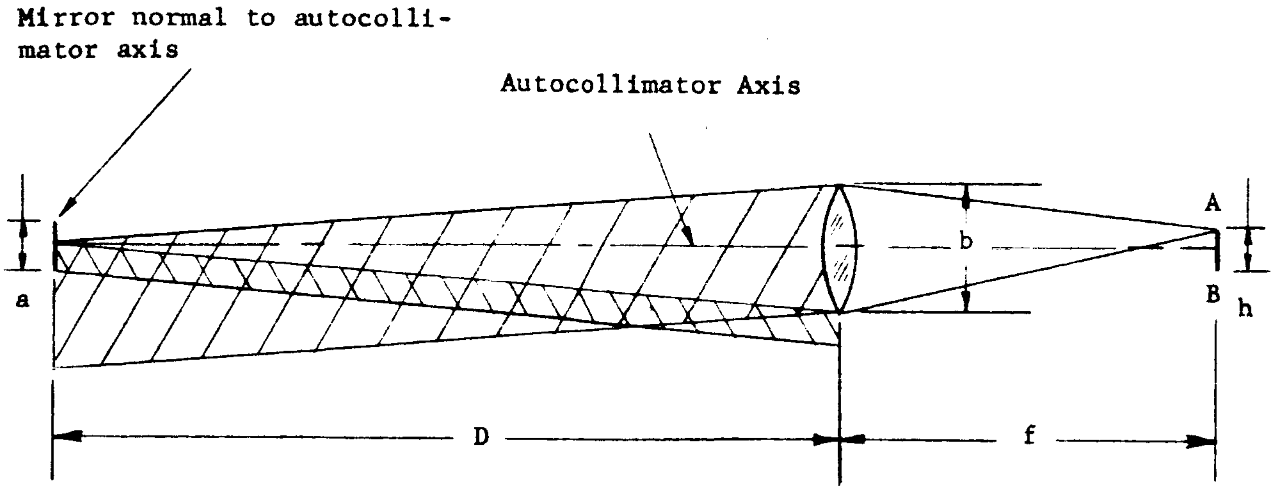
For a mirror azimuth deviation $\Delta\theta$ the horizontal image motion is

$$\Delta w = 2f\Delta\theta$$

from which the basic autocollimator radiant sensitivity is found to be

$$\frac{\Delta P}{\Delta\theta} = \left(N \frac{a^2}{f^2}\right)\left(\overline{Kv} \frac{bf}{D}\right) 2f$$

$$= \frac{2N\, a^2\, \overline{K}_v\, b}{D}$$



Light from points A and B is reflected back completely outside objective lens aperture, and these points in image are, therefore, completely dark. Brightness distribution in image has the following form.

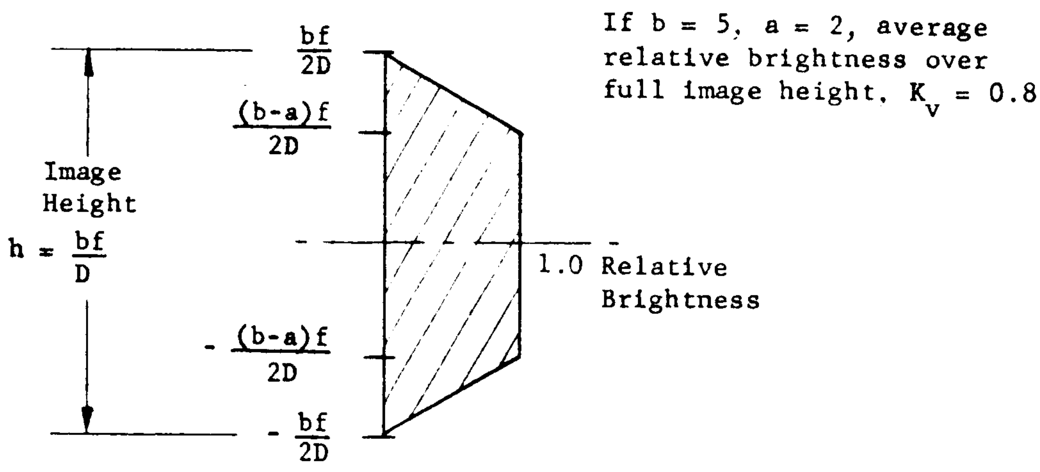


Figure 5. Autocollimator Aperture Vignetting and Image Brightness Characteristics

3. Gain Reduction Factor (See Figure 6)

Metallic reflections: 13 aluminum

at .9 or higher =	$.9^{13}$	=	.25

Air Glass Transmission:

29 at .96 =	$.96^{29}$	=	.307

IRT-211 pellicle coating transmission:
(See Figure 7)

	$.85^{2}$	=	.72

Atmospheric transmission:

	$.92^{2}$	=	.84

Filament Coverage (for G.E. 1630 with 1 x 2 mm coiled filament) $\approx$ .70

The gain reduction factor K_e is the product of these terms, K_e = .033.

The true autocollimator radiant sensitivity is

$$\frac{\Delta P}{\Delta \theta} = \frac{2N\,\alpha^2 \, \bar{K}v\; b\; K_e}{D}$$

and if D = 1000 ft = 12000 inches

and θ = 1 arc second = $4.8\text{x}10^{-6}$ radians

$$\frac{\Delta P}{\Delta \theta} = \frac{2 \times \frac{350}{\pi} \times 4\text{x}.8\text{x}5\text{x}.033 \times 4.8\text{x}10^{-6}}{12000}$$

$$\frac{\Delta P}{\Delta \theta} = 4.6\text{x}10^{-8}\text{watts/arc second}$$

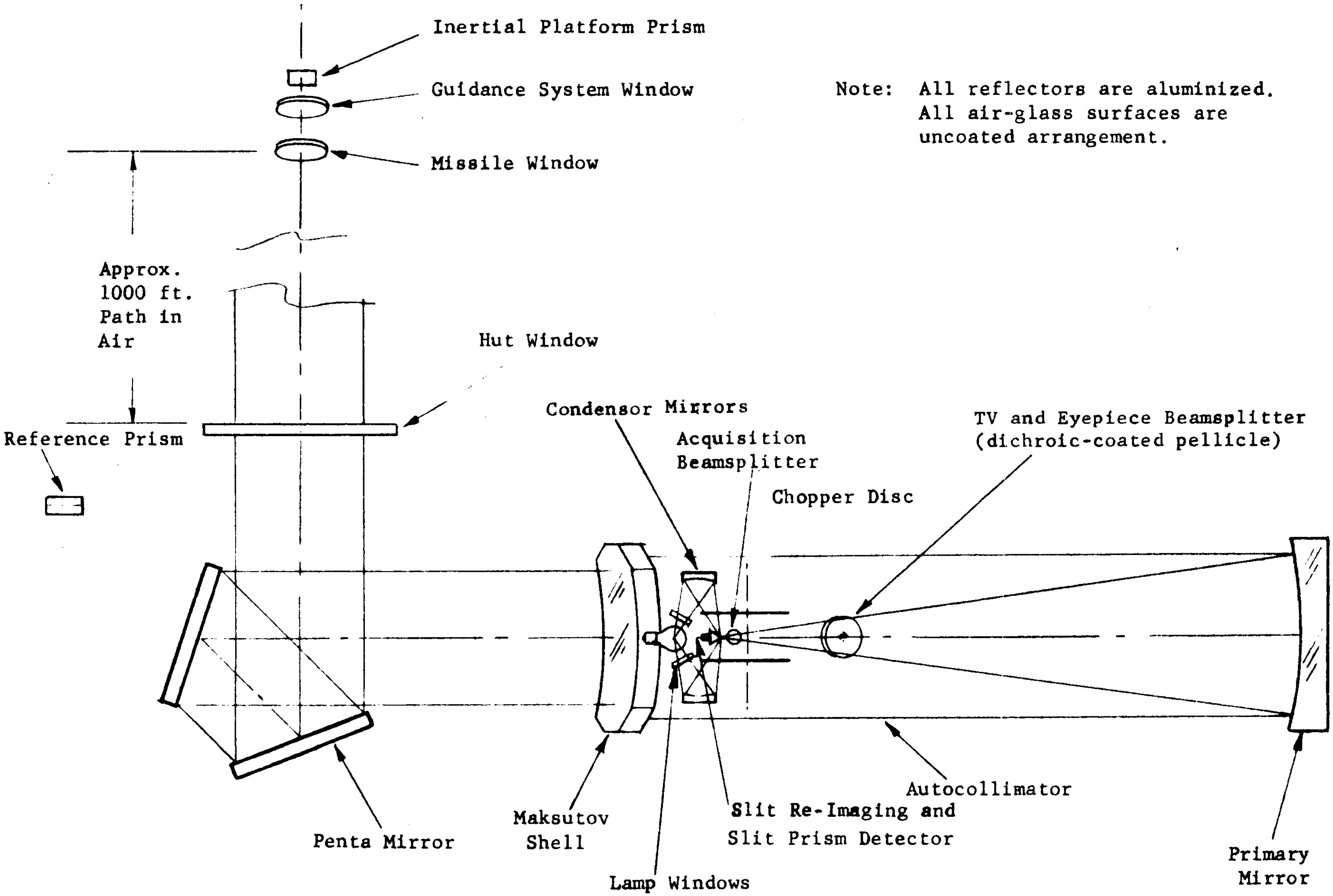


Figure 6. Optical Element Loss Computation

4. Detector SNR

The DC signal available for a mirror deviation of 1 arc second is 4.6×10^{-8} watts.

For square wave chopping the RMS signal will be approximately one-half of the DC level

$$P_{RMS} = 2.3\times10^{-8} \text{ watts}$$

The minimum energy detactable by a given detector is

$$P_{min} = \sqrt{\frac{A\Delta f}{D^*}}$$

A = detector area in cm^2 = $.04cm^2$ for 1x4mm detector

Δf = measuring bandwidth = (say) 5 cps

D^* = detector detectivity in autocollimator

and

$$SNR = \frac{P_{rms}}{P_{min}}$$

gives the desired autocollimator SNR for 1 arc second mirror deviation.

A typical lead sulfide detector optimized for this application can be shown (Infratron Lead Sulfide Technical Bulletin No. 2, Infrared Industries, Inc.) to have a detectivity of

$$D^* = 4\times10^{10}$$

therefore

$$SNR = \frac{2.3 \times 10^{-8}}{\sqrt{\frac{A\Delta f}{D^*}}} = \frac{2.3\times10^{-8} \times 4\times10^{10}}{\sqrt{.04 \times 5}} = \frac{920}{.45}$$

$$SNR = 2040$$

The RMS signal voltage from the PbS detector (from Infration Catalog) is

$$\frac{V}{\theta} = 1 \times 10^{-3} \ \frac{\text{volts}}{\text{arc second}}$$

The SNR of 2040 for 1 arc second mirror deviation is clearly very large. This level is sufficiently high to avoid SNR reduction by the detector preamplifier. Thus, with reasonable care in design it is possible to maintain the inherent autocollimator noise well level below the largest uncontrollable noise sources: air path shimmer and external extraneous light. These latter, based on previous experience, should normally not prevent attainment of 1 arc second angular resolution if the measuring bandwidth is sufficiently narrow.

B. AUTOCOLLIMATOR MEASURING CHARACTERISTICS

1. The Measuring System

Autocollimator measuring characteristics are determined basically by the objective lens and mirror apertures and by the operating distance. For the LR2A system with an 8 inch wide objective lens and a 2 inch wide mirror, the system transmission characteristics are shown in Figure 9 in terms of the angular range over which an axial object point may be sensed as a function of operating distance. It is seen that with the mirror centered, full gain out to ±1 arc minute exists up to 450 feet, but that at 1000 feet full transmission exists up to ±26 arc seconds, while the total acquisition range is ±42 arc seconds.

These figures do not, however, represent actual autocollimator performance, for the effect of the necessary detector slit has not yet been considered. At this juncture regard must be given to optimizing LR2A operation

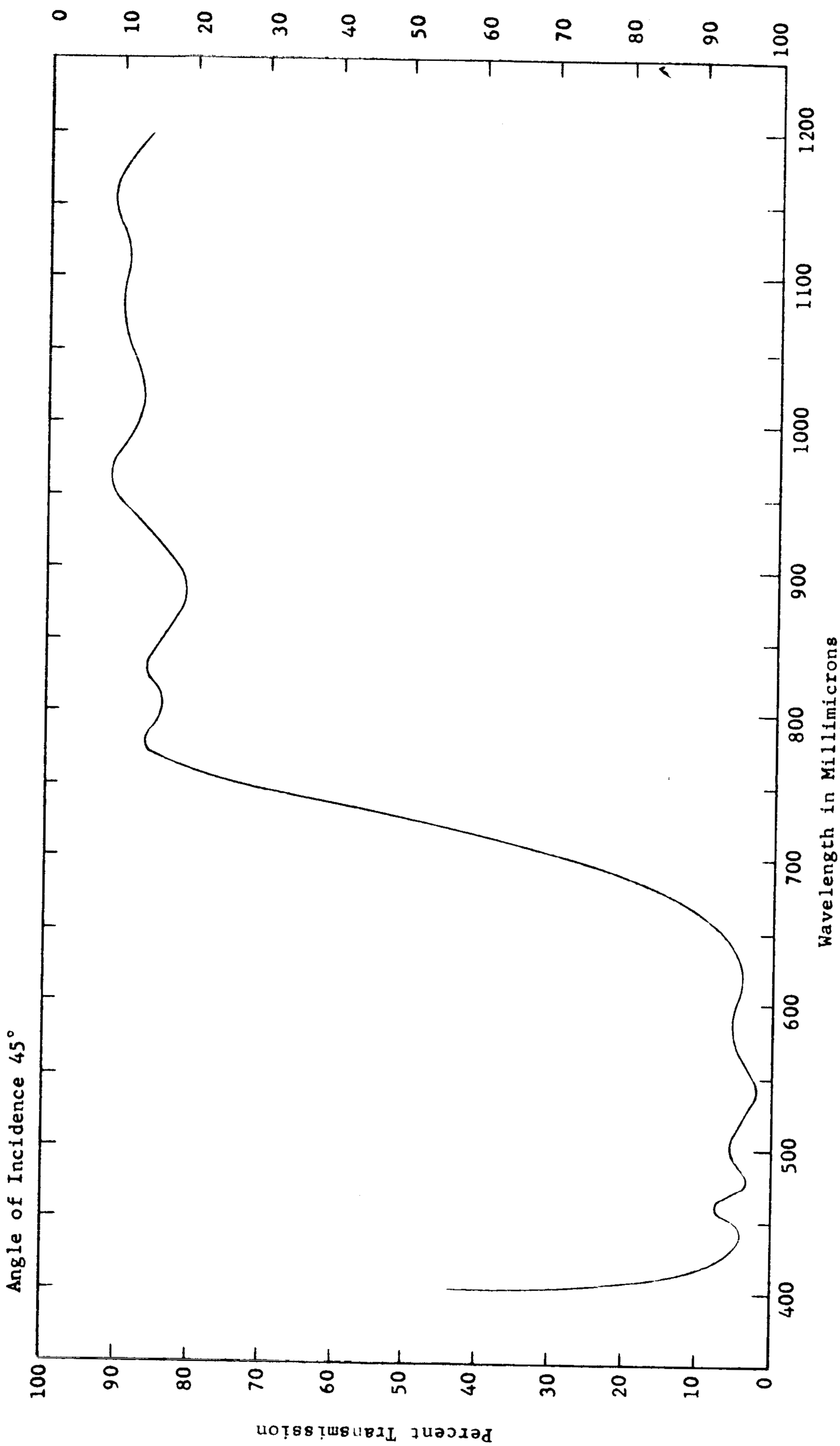


Figure 7. IRT-211 Dichroic Coating Transmission

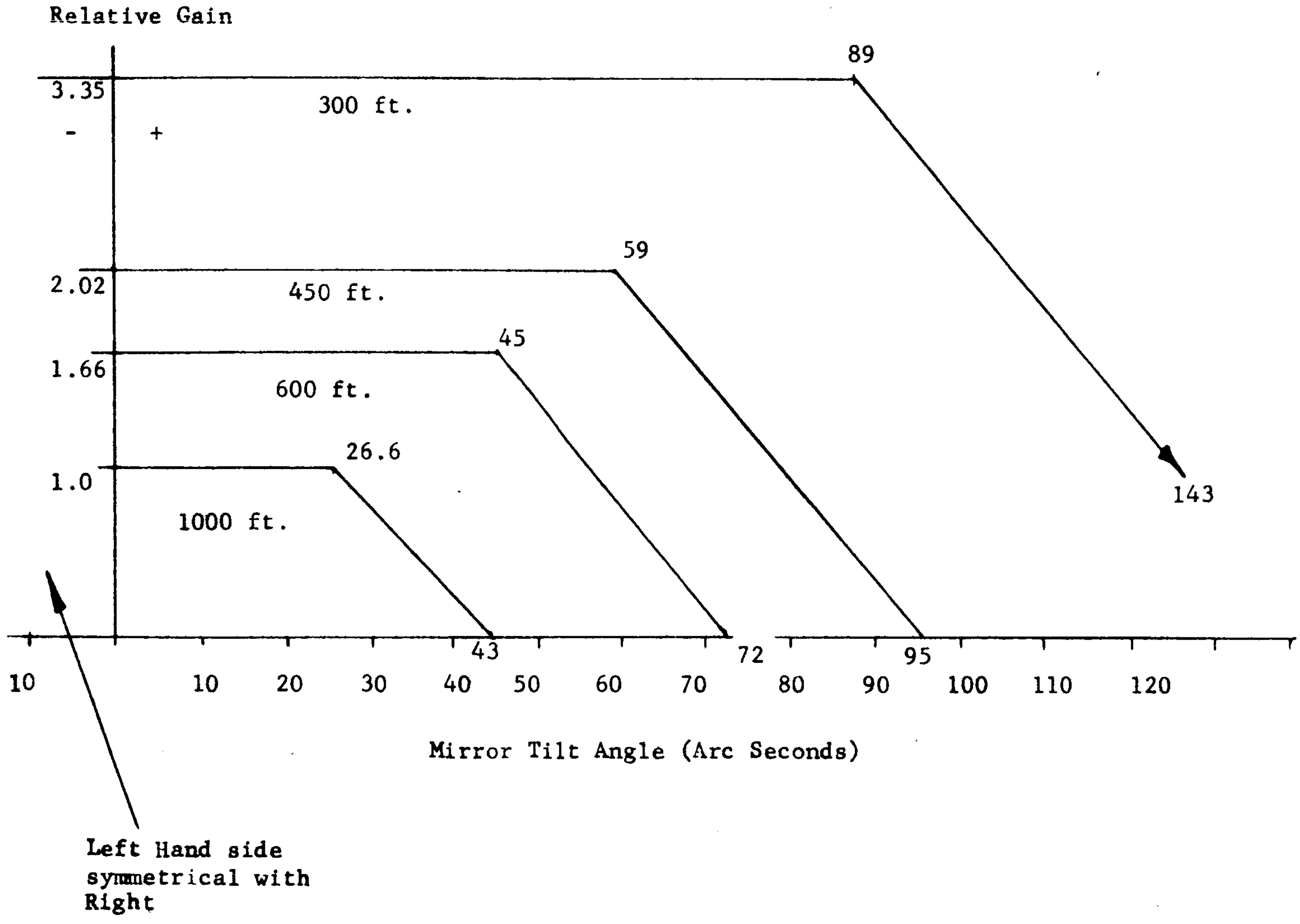


Figure 8. Autocollimator Transmission Characteristics With 8-Inch Aperture and 2-Inch Mirror for On-Axis Point

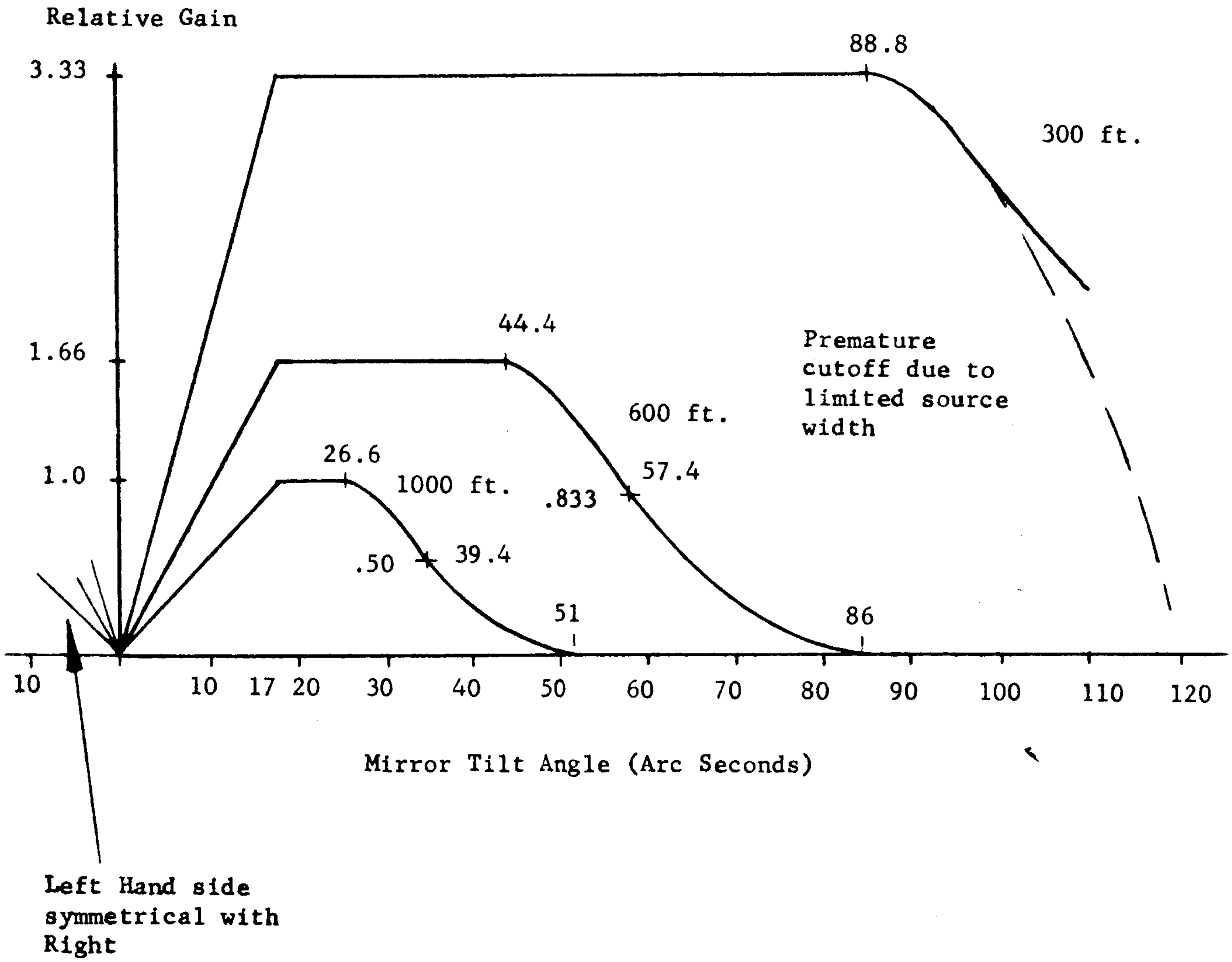


Figure 9. Autocollimator Measuring Characteristics With 8-Inch Aperture, 34 Arc Second Sensing Prism Slit and 2-Inch Mirror

for the actual distances at which it will be used. The first application will involve a base line of 300 feet and an elevation angle of 30 degrees for a total operating distance of 350 feet. The most advanced application foreseen, the C-5 Saturn, will double these figures, and the maximum operating distance will, therefore, be about 700 feet.

The detector slit constitutes a dark zone between the two adjacent out-of-phase light source images on the sensing prism. The angular width of the slit determines the proportional measuring range of the autocollimator wherein the light intensity on the detector increases in direct proportion to the mirror deviation angle from null. The proportional range is nevertheless basically limited by the aperture and operating distance factors above. The slit width, by separating the bundles of light corresponding to the two phases of transmitted light, reduces the dynamic sway tolerance of the system while increasing the angular measuring range, and thus a compromise must be reached between these two effects.

Since 500 feet is the proportional mean distance between 350 and 700 feet, LR2A operation will be optimized for 500 feet. By simply changing the sensing prism it can be optimized for other distances in the future if so desired. If 1-inch bundle separation of the two light phases is allowed at 500 feet, the slit angular extent is 34 arc seconds, its linear width is .005 inch, and the autocollimator proportional measuring range at any distance up to 1000 feet is ±17 arc seconds. Figure 9 summarizes the overall angular measuring characteristics of the LR2A at several operating distances with the platform prism centered.

With the system nulled, the permissible dynamic prism sway for no more than 25 percent gain change is ±3.2 inches at 300 feet, ±3 inches at 500 feet and ±2.5 inches at 1000 feet.

These performance characteristics are wholly consistent with the intended function of the LR2A.

2. Acquisition Indication

The dichroic beamsplitter required to send all visible light from the missile to the TV camera conversely removes all visible light from the autocollimator sensing system. Thus the autocollimator radiant signal cannot be seen, and acquisition, therefore, cannot be observed visually or in the TV camera.

An acquisition signal is necessary primarily to differentiate between the absence of a measuring error signal at null and its absence due to no light being returned to the autocollimator. So long as a measuring error signal is present it provides sufficient acquisition information but its fluctuations and possible absence at null make it useless for automatic control purposes.

Acquisition sensing near null is provided by an acquisition detector operating near an autocollimated focal plane separated from the sensing prism by an uncoated glass beamsplitter. This detector sees a large signal at the fundamental modulation frequency when the measuring system is at null. An acquisition relay is controlled by the acquisition detector signal summed with the azimuth measuring signal. In operation the latter is the first to appear and insures that an acquisition indication is given only when a measuring signal is present. As the measuring signal reduces near null, the acquisition detector then assumes control and maintains continuity of the acquisition indicator through null as required.

Acquisition is indicated by a light on the control panel and by a relay closure which may be used for remote switching control.

C. REFERENCE PRISM DESIGN

1. Basic Geometrical and Radiometric Considerations

The reference prism serves two primary functions:

(1) As a presumably more stable element than the autocollimator it permits checking for possible drift in the autocollimator.

(2) It is a transducer through which the non-visible autocollimator line of sight may be transferred to a survey theodolite for determination of the alignment azimuth direction.

The reference prism also serves to check out the autocollimator for proper operation and can be used for gain adjustment as well.

In order to serve these functions the reference prism should satisfy three criteria. It should:

(1) Produce the same size diffraction pattern as the platform prism.

(2) Provide the same radiometric gain as the platform prism at one operating distance.

(3) Simulate the geometrical effects of the platform prism.

These criteria are in conflict. In order to provide the same size diffraction pattern as the platform prism and satisfy the first criterion a reference prism of the same aperture as the platform prism must be used.

The second criterion can be satisfied through the use of an optical attenuator or by a reduction in the size of the reference prism aperture through the use of a mechanical attenuator (mask).

The third criterion cannot be met if simulation of large operating distances is desired. Thus while the platform prism will form an autocollimated image of height.

$$h = \frac{bf}{D} = \frac{5 \times 30}{12000} = .012 \text{ inch}$$

at 1000 feet, the reference prism will form an image of the same height as the lamp filament, or .080 inch. No error arises from this source if the autocollimator sensing prism slit whose effective angular height is

$$\frac{.080}{30} = .0027 \text{ radian} = 9 \text{ arc minutes}$$

is oriented normal to the penta prism principal plane within

$$\frac{2 \times 5 \times 10^{-6}}{2.7 \times 10^{-3}} = 4 \times 10^{-3} = \pm 13 \text{ minutes},$$

a condition easily achieved.

Since one of the primary considerations of the reference prism is to provide a stable calibrating device for setting the LR2A gain adjustment, a mechanical attenuator of appropriate size is permanently installed in front of the face of the prism. An optical attenuator, although it can accomplish the same result, is less stable, may introduce spectral descrimination and wedge angle, and is therefore less desirable than the mechanical attenuator employed.

To compensate for the increase in gain a mask with an aperture of .63" x .63" is inserted in front of the reference prism. This, along with a calibration wedge provided gives a convenient calibration for the 1000' operating distance. The use of a mask such as this satisfies the second criterion and compromises with the first. Although a decrease in the reference prism aperture will result in a corresponding increase in diffraction pattern size on the sensing prism, this is partially compensated for by the effectively increased size diffraction pattern which is a result of atmospheric shimmer during target prism viewing.

2. Gain Adjustment

To insure satisfactory operation of the LR2A in the inertial platform azimuth alignment loop, its input-output gain must be adjusted close to a specified value of 100 millivolts per arc second for any operating distance. The gain variation with distance is an inverse relation, and a calibrated potentiometer is provided to adjust for the actual operating distance once the gain at 1000 feet is known.

The simplest and most obvious gain adjustment method is to insert into the optical path a wedge of known angular deviation (say 15 arc seconds) when the LR2A is nulled with the reference prism. With the wedge in the optical path and oriented to produce, say, clockwise deviation, the range potentiometer knob is adjusted to give a 15 arc second reading on the error signal meter. Symmetry is checked thereafter by rotating the wedge 180° to obtain deviation in the counterclockwise direction which should result in a 15 arc second reading of opposite sign.

The setting corresponds to the 0 db point - a distance of 1000 feet with no optical elements (windows) in the path. The knob should be locked at this point and the moveable dial rotated until 0 db marking falls under the knob pointer. The dial is then locked in place.

To compensate for various distances and the inclusion of windows in the optical path references should be made to a chart provided with the instrument.

The correction factor is arrived at by adding the db levels corresponding to the number of elements in the path and setting the knob pointer to the new db. level. For example: if the range is 400 feet and there are 2 windows in the optical path, the db correction for range is -8.30 and the correction for window losses is +2.80 db. The total correction is

-8.30db	400 feet
+2.85db	2 windows
-5.45db	

The knob pointer should be set to 5.50db.

Table 1 provides correction factors needed to set the gain calibration for almost any situation.

3. Design Considerations

a. General

There are two basic ways in which the reference prism could be employed to transduce the autocollimator line of sight to an observable survey direction:

(1) Both the LR2A and the survey theodolite would look into the roof face of the reference prism at approximately the same elevation angle.

(2) The reference prism would be provided with one end face accurately normal to the autocollimated roof face direction. The LR2A would look into the roof face and the survey theodolite would look horizontally at the end face.

The first method is generally preferable and will be employed in the LR2A system.

There are several factors which are important in achieving the desired LR2A alignment accuracy.

GAIN ADJUSTMENT FACTOR

Distance	Gain Correction
1000 ft	0db
900 ft	-.90
800 ft	-2.10
700 ft	-3.40
600 ft	-4.70
500 ft	-6.30
400 ft	-8.30
300 ft	-10.80
200 ft	-14.50
Windows	**Gain Correction**
0	0 db
1	+1.40
2	+2.85
3	+4.25
4	+5.65
5	+7.10

Table 1

b. Prism Geometry

The reference prism and the platform prism must be arranged to ensure that they will indicate the same azimuth when autocollimated with the LR2A. In this case azimuth is defined as the direction in a horizontal plane assumed by a levelled autocollimator nulled with the prism.

The alignment plane is elevated at an angle of 30°. The reference prism is adjustable by changing wedge-shaped spacers to nominal elevation angles of 25°, 30° and 35°, and is intended to accept a ±5° range of LR2A elevation angle (β) in each position. If the indicated azimuth (α) of the reference prism is to change no more than 1 arc second over this elevation range due to cross-level error, the prism apex deviation angle from horizontal (θ) must be no greater than

$$\theta \text{ max} = \frac{\Delta\alpha}{\beta} = \frac{\frac{1}{200,000}}{\frac{1}{12}} = \frac{12}{200,000} \text{ radians} = 12 \text{ arc seconds}$$

Allowing some tolerance for the levelling process, the reference prism end face is specified to be normal to its apex within 6 arc seconds. Since the apex must be levelled for prism elevation angles (β) of up to 40°, the end face must be truly normal to the apex, and not just normal to it in one plane including the apex.

In the reference prism design due regard must be given to the wavelength difference between the visible region and the Lr2A spectral operating region. Because of the dispersion of optical glasses, any large amount of azimuth wedge, commonly known as pyramid will cause a significant difference in the visual and infrared autocollimated directions. It has been established that for a standard optical glass, such as BK7, this difference will be less than 1 arc second if the pyramid angle is less than 10 arc seconds.

c. Coatings

The wide spectral region of interest in the LR2A system, the 2 octaves from 0.5 to 2.3 microns, generally negates the interference effects of 1/4 wave anti-reflection coatings. Nevertheless, a slight benefit could be derived from the smaller discontinuities in index of refraction which occur when a coating of intermediate index is utilized.

Ordinary anti-reflection coatings such as magnesium flouride and silicon monoxide would be attacked to some extent by the Cape Canaveral environment. Also, anti-reflection coatings offer no protection to refractive elements as they do to aluminized reflecting surfaces. In view of these drawbacks, and the extremely slight benefit derived, all refractive elements in the LR2A will remain uncoated.

All front-surface reflecting surfaces are to be coated with vacuum deposited silicon monoxide for mechanical protection. To avoid significant variation in reflectance over the wide spectral operating range this coating must be thinner than normal. A reasonable thickness in this case is 1/10 wavelength of green light, or approximately .05 micron.

d. Adjustment and Survey

The reference prism, after installation must be adjusted and surveyed to establish the alignment direction of the LR2A. Initially, the reference prism is installed and oriented roughly in the alignment direction. The prism elevation angle is adjusted by selection of the appropriate spacer to the value (25, 30 or 35°) closest to the alignment line of sight.

The prism apex is levelled by adjustment of the levelling mechanism while referring to the prism end face with a levelled, autocollimating theodolite. The theodolite should have a levelling accuracy of 4 arc seconds or better, a value typical of second order survey instruments such as the Kem DKM-2 and the Wild J-2.

The LR2A is aligned with the platform prism under standard conditions as described elsewhere, after which it is aligned with the reference prism. The latter is adjusted in azimuth until the LR2A is autocollimated and nulled. The levelling of the reference prism is checked with the theodolite, but should not require readjustment.

The penta mirror is moved away from the reference prism and a first order survey theodolite set up to look into the prism at the alignment elevation angle. The theodolite must be levelled within 2 arc seconds for this measurement, which involves transferring azimuth from a line of sight elevated approximately 30 degrees. After levelling and plumbing over a benchmark, the theodolite is autocollimated with the reference prism and the azimuth circle reading recorded. It is then positioned to view a distant bench mark, preferably far enough away to obviate refocussing the theodolite and the azimuth reading recorded.

The difference between the two readings when added to the previously surveyed azimuth of the line between benchmarks, gives the azimuth of the LR2A alignment direction.

e. The Platform Prism

All of the alignment factors above pertain also to the platform prism. During alignment it must be levelled and tilted such that its $\beta\theta$ product with respect to the alignment plane is less than 1 arc second. If the tilt can be adjusted to correspond within, say, 1° of the alignment plane, the prism apex levelling tolerance is ±1 arc minute. Increasing the tilt misalignment correspondingly decreases the levelling tolerance.

Similarly, since the platform prism will be oriented on the platform using visual instruments, the pyramid tolerance on the prism probably should be ±15 arc seconds or less.

D. TV CHARACTERISTICS

1. General

The TV vidicon becomes an integral part of the LR2A optical system, and there are constraints imposed on the allowable vidicon location by the camera mechanical design. In addition, the light energy available at the vidicon cathode through the LR2A optics is sufficiently low to require use of the most sensitive possible vidicon along with a specially coated dechroic beam-splitter.

As indicated immediately below, and in other sections of this report, satisfactory optical and mechanical design integration of the General Electric 4TE-9 series camera has been achieved, and sufficient light is available for good visibility in daylight and under good artifical illumination.

The vidicon cathode lies directly in the focal plane of the auto-collimator objective. Thus, in the absence of an intermediate focal plane, the crosswire reticle pattern required for pointing the LR2A must be made a part of the cathode if it is to be sharply in focus. Vidicons with custom reticle patterns engraved directly on the photoconductive surfaces were obtained on special order from General Electric and sucessfully employed.

2. Geometrical Characteristics

The TV vidicon, whose 525 line raster size is 1/2 x 3/8 inch, is located at the focus of the 30 inch focal length autocollimator objective lens. The viewed field size is:

5 x 3.75 ft. at 300 ft

16.7 x 12.5 ft. at 1000 ft.

The 2-inch inertial platform prism covers 14 lines at 1000 ft. and 46 lines at 300 ft., and would easily be seen on the TV screen if it were open to view.

For pointing purposes a crosswise reticle pattern must be enscribed in the vidicon phospher. A line width of about 5 mils which subtends 2-inches at 1000 feet and 2/3 inch at 300 feet, will cover the same number of lines as the platform prism at the larger distance and will be clearly visible. It should permit centering the autocollimator line of sight on the missile window within ±1/2 inch or less.

The visual reticle is the same size as the TV reticle.

3. Vidicon Photometry

The light intensity on the vidicon face, I, is given by

$$I = \frac{I_o\ K}{4(f/no.)^2}$$

where

I_o = source brightness = 1000 $\frac{\text{lumens}}{\text{ft}^2}$ from a white surface at noon

$$f/no. = \text{f - number of objective lens} = \frac{\text{focal length}}{\text{average diameter}}$$

$$= \frac{30}{6.7} = 4.5$$

K = gain reduction factor as follows:

Metallic reflections:	4 at .85	= 85^4 =	.52
Air-glass transmission:	4 at .96	= $.96^4$	.85
IRT-211 pellicle reflection			.85
Atmospheric transmission			.92
		K =	.35

and

$$I = \frac{1000 \times 3.5}{4 \times (4.5)^2} = 4.3\ \frac{\text{lumens}}{\text{ft}^2}$$

Thus a maximum faceplate illumination of 4.3 $\frac{\text{lumens}}{\text{ft}^2}$ is available at the vidicon. The high sensitivity 7226 vidicon or its equivalent to be used in the General Electric 4TE9 series TV camera provides good picture quality at illumination levels below 0.1 $\frac{\text{lumens}}{\text{ft}^2}$. Consequently, there is ample light for a good picture late in the day or under overcast conditions.

During final testing of the LR2A the NASA supplied T.V. cameras were seen to provide excellent picture quality under all daylight conditions. The cameras were also used at night and were found to provide a usable picture of the target prism when illuminated by a flashlight held a few feet from the prism. On this basis, the missile window should be clearly visible at night if under spotlight illumination.

E. ELECTRONICS

1. General Description

The main purpose of the electronics is to provide an automatic indication of the rocket's angular deviation. This is accomplished by means of sensing the phase and magnitude of the returning light beam. A distance gain control is provided to set the overall gain factor to .1 volt/sec. At the normal operating distance an input signal level of 1×10^{-3} volts is expected at the preamplifier. In addition to an indication of the angular deviation a signal is provided to indicate acquisition of the mirror since the error signal will be zero at null. It thus becomes necessary to differentiate between no signal (platform prism not acquired) and null signal, (platform prism acquired). The presence or absence of a +28 VDC signal indicates whether the system is acquired or not.

Relays are provided for controlling the penta position elevation angle and power remotely from the blockhouse. The theodolite functions may also be controlled from the console.

The angular deviation and penta position are indicated on two large 7 inch meters. The scale background will be light grey in color so as to prevent blossoming, as might happen with a white background, on the TV monitor. This color was specifically developed for meters to be used in closed circuit television.

2. Detectors

The returning alignment error signal is detected by an active PbS detector which is arranged in a balanced bridge arrangement with a similar inactive PbS unit. A bridge arrangement was chosen to provide temperature compensation. Both detectors are from the same manufacturing batch and have approximately the same internal resistance 200KΩ. The second detector is masked so it does not respond to any light radiation.

Another PbS detector is used for an acquisition indication at null. Since acquisition at null is a gross signal intended for acquisition indication, no attempt was made to provide temperature compensation. The load for the acquisition detector then becomes simply a resistor as no temperature compensation is necessary.

3. Preamplifier Assembly

Two preamplifiers are provided. Preamplifier A1 (Figure 3) is a Taber amplifier Model #198-3. This unit incorporates a silicon field effect transistor on the front end with an input impedance of nominally 10 megohms and an equivalent broadband input noise of 25μv. A high input impedance is desirable from the standpoint of obtaining maximum signal responsivity from the detectors. The preamplifier has a gain of 33. With the expected input signal of 1×10^{-3} volts/sec at 1000 ft the output level A1 will be .033 volt/sec. The Taber amplifier was chosen as it will perform satisfactorily with the expected signal levels and is more than sufficient for the intended purpose.

Preamplifier A2 is a Perkin-Elmer designed amplifier for acquisition indication when the system is nulled.

Synchronous demodulation is necessary for incoming signals. The means for synchronous demodulation is provided by a photo transistor 2N986 which receives the light reflected from the mirrored face of the chopper blade. The photo transistor provides a 28 volt peak to peak square wave used as the reference phase for the synchronous demodulators.

Control of the phasing of the photo transistor is accomplished by mechanical positioning of the photo transistor.

4. Console

a. Error Channel

The incoming signal .033 volt/sec from preamplifier A1 is fed through a 5.5:1 voltage dividing network which includes the range control, potentiometer R2. At the top of the range control the signal level will be .0033 volt/sec. The output of the range control is fed to a series variable resistor R3 which varies the gain of amplifier A3 from 100 to 10. A3 is normally set at a gain of 30. The output of A3 .1 volt/sec is fed to a synchronous demodulator which converts the 266 cps signal to a proportional d.c. level whose polarity is determined by the phase of the input signal: + d.c. for 0°, -d.c. for 180°. This d.c. level is fed through a d.c. amplifier with a gain of 1.30 which consists of a differential amplifier composed of two balanced transistors and an emitter follower. The output signal from the emitter follower is fed back to the base of Q1b. The feedback serves two purposes:

(a) It serves to compensate for the base-emitter voltage drop variation with temperature of the emitter follower, and

(b) The output impedance is lowered beyond what would normally be obtainable from an emitter follower. The output impedance is nominally 20 ohms.

The output of the d.c. amplifier is then returned to the blockhouse and is also sensed at the chassis by a 50-0-50 μa meter connected as a voltmeter — the meter indicating the angular deviation. It would have been possible to provide a d.c. amplifier with a larger gain, but since there is sufficient a.c. gain present, a complex d.c. amplifier, chopper stabilized or the equivalent, was not necessary.

The output of amplifier A3 is simultaneously fed to a full wave rectifier T1. This d.c. output is used to provide the signal to actuate the acquisition relay circuit. The error signal is used to provide the acquisition signal so as to indicate acquisition off null only when an error signal is present.

b. Acquisition Channel

Output from preamplifier A2 is fed to a potentiometer R3 gain control. Amplifier A4's output is fed to a second synchronous demodulator which again provides a proportional d.c. signal whose polarity depends on the phase of the returning light beam. To restrict the range of the acquisition channel to a narrow field of view in the vicinity of null, a shunting diode is used to pass only one phase. By suitably offsetting the PbS detector the range of null acquisition is reduced.

The output of the null acquisition channel and the error acquisition are fed simultaneously to an acquisition gain control R5. The level of acquisition is controlled by R5 which feeds the base of transistor Q3. Transistor Q3 is normally biased on by the slight amount of leakage current at the base. Q3 is conducting lightly so that the potential at its collector is approximately 7.9 volts. This level is determined by resistor R33 and resistor R12. An increase in input signal from either acquisition channel will cause Q3 to conduct more heavily. At this time, transistor Q3 goes into a low voltage condition. Q4, a silicon controlled switch had been held in an off condition due to the positive 7.9 volts on its cathode. When Q3 drops to a low voltage condition, the voltage on the gate of Q4 provided by the restive divider is sufficient to trigger on Q4. A reduction in the input level to Q3 reverses the process and triggers off Q4.

The above circuit was chosen so as to provide a sensitive, repeatable triggering point for acquisition.

5. Control Functions

a. Penta Actuator

The penta actuator may be driven in either direction by means of two relays from the console by a momentary single pole center off toggle switch or from the blockhouse by two incoming lines providing appropriate signals to the relay coils. The penta position is indicated by a meter on the console. The meter indication is obtained from a 10 turn 10KΩ potentiometer driven by the lead screw. Two relays are used instead of a single polarized dual coil relay as they are more rugged and their contacts have a larger current carrying capacity.

b. Elevation Actuator

The elevation actuator may be controlled in a similar fashion to the penta actuator except for dynamic braking. The elevation angle may be discerned from the television monitor.

c. Power

The theodolite power is controllable by a push button on the console or by two incoming lines from the blockhouse. The necessity for two incoming lines is dictated by the fact that if a one line is used, it is impossible to turn off the theodolite from the blockhouse once it has been turned on at the console.

F. HUT DESIGN

The hut in which the LR2A is to be installed shall afford the instrument complete protection from the adverse Cape Canaveral environment. Provisions are to be made for reasonably constant temperature, low humidity, freedom from dust, and shielding of the instrument from direct sunlight. Along with the basic hut characteristics implied by these functions, there are other design considerations necessary to satisfy the installation, alignment and operating requirements of the LR2A. The following items of the suggested form are to be supplied by NASA except where specifically indicated that they will be supplied by PECO:

(1) A truly stable pier is required for the LR2A and its reference prism, since any shift in the pier will be evidenced only by resurveying of the reference prism. A poured concrete pier, preferably anchored to bedrock, should provide the required stability. A pier height of approximately 39 inches above floor level provides for a six foot height to the eyepiece for visual observation of the missile through the instrument along with a reasonable (about 4 foot) height for the first order theodolite used to survey the reference prism. A guard rail anchored to the hut floor will be provided to stradle the instrument so as to preclude the possibility of operator damage to the instrument when looking through the eyepiece. A one foot high step will facilitate viewing

through the eyepiece. This rail will also serve to provide a framework for an instrument cover which will be discussed below.

(2) A window must be installed in the hut to afford an unobstructed line of sight to the missile platform prism. This window shall be 12 inches wide by 36 inches long so as to allow for a 10° change in elevation angle and accomodate the respective aperture and penta travel of the LR2A. This large size window completely eliminates the need to move the window during fueling to compensate for shrinkage of the missile.

The window may be mounted in a moveable frame which will accomodate an elevation range of 20° to 40°. The mounting should prevent leakage of internal conditioned air. Figures 10 (Drawing Number 563-0012) shows the location and suggested mounting arrangement for this window. The orientation of the window is approximately 18° to the vertical so as to eliminate direct reflections back into the LR2A.

The window must have constant, and preferably zero azimuth deviation within ±1 arc second along the entire range of penta scan. Perkin-Elmer will supply unmounted windows 36 inches by 12 inches by 1/4 inch thick which are cut from selected Libby-Owens-Ford twin polished plate glass.

These windows were found to exhibit a maximum in azimuth deviation of ±1 arc second with a maximum change in azimuth deviation of ±1 arc sec. across their entire clear aperture.

(3) The hut should permit direct ingress, without twisting or turning of the 100 inch wide LR2A. This is easily accomplished by leaving one wall of the hut open until the instrument is placed on the concrete pier. An arrangement of this type would permit the use of a fork lift truck and eliminate the need for any large swinging doors. Consideration should also be given to providing a means of removing the LR2A should it be necessary. The previously mentioned wall could be made removable for this reason.

(4) Adequate working space on all sides of the LR2A pier is a requirement for effective operation and maintenance of the instrument. It is also necessary to allow for space off the reference prism end of the pier for a man and a theodolite necessary to level the reference prism. The required space and orientation of the instrument with respect to the hut is shown in Figure 10.

(5) There must be a benchmark and space in front of the reference prism for a man and the first order theodolite needed to survey the prism azimuth. The theodolite will normally be looking up at a 30° elevation angle. The surveying

operation necessitates a benchmark in the hut where the survey theodolite will be placed and also an opening to permit the survey instrument to view an external benchmark. Since a door is required for an operator to have access to the hut, a convenient place to locate a small hinged opening for survey theodolite viewing would be in this small door. Figure 10 illustrates the recommended location of the door and opening.

(6) Electrical connections to the LR2A will be most convenient if brought in through conduit in the floor to a distribution box mounted on the side of the concrete pier between the guard rails, and also minimizes any strain which might be transferred by electrical cables to the instrument. All cables to the instrument will be clamped to the steel bed to eliminate strain variations during elevation rotations.

(7) The hut interior shall be epoxied to minimize dust generation and retention.

(8) During periods of non-operation a cover for the entire LR2A should be used. Since the penta prism has its own metallic cover, and the previously described rail forms a frame over the autocollimator, a flexible cloth type of cover seems appropriate. Perkin-Elmer will supply such a cover that may easily be draped over the entire instrument. A source of

heat under the cover, such as a light bulb, is also suggested so as to insure an absolutely dry environment for the instrument. The cover material will be vinyl or neoprene coated nylon which combines the properties of a poor adhesion surface for dirt particles and insensitivity to fungus growths.

(9) The incidence of sunlight directly on the window may have adverse effects on the operation of the LR2A. To preclude this possibility along with precipitation on the hut window, a shade must be provided. The approximate size and mounting arrangements of this shade are shown in Figure 10. The shade may be designed so that it also performs the dual function of protecting the window during non-operation and adverse weather. In order to accomplish this the shade is hinged so that it easily folds flat against the exterior of the hut and is locked in place by several wing nuts tied directly to the hut itself.

(10) The hut must also be oriented so as to avoid having the LR2A see sunlight directly reflected from the missile skin. This condition is best met if the instrument viewing direction is due South, and NASA has agreed to provide this orientation.

G. LR2A INSTALLATION

The installation of the LR2A into its hut should be accomplished quite readily if the previously discussed hut design objectives are closely followed. The actual installation will be a two step operation.

Figure 11 (Drawing Number 563-0015) shows the stainless steel bases required for the theodolite and smaller reference prism. The first step of the installation involves the mounting of the two baseplates to the concrete pier and the placement of the grout. All anchor bolts (supplied by NASA) are located in the concrete pier prior to placement of the baseplates. This is easily accomplished with the aid of a wooden template which will be supplied by Perkin-Elmer. The template is shown in Figure 12 (Drawing Number 563-1194). After the concrete and anchor bolts have set, the baseplates are installed and grouted in. The leveling screws used during this operation are removed after the grout has set.

The second step of the installation operation involves the actual placement of the LR2A and the reference prism. The autocollimator and penta set will be completely aligned at Perkin-Elmer prior to shipment to NASA. Since it is extremely dangerous to ship the LR2A in this condition, it shall be disassembled into major sub-assemblies prior to shipment and re-assembled by Perkin-Elmer personnel at the destination.

A fork lift truck will lift the instrument and place it on the baseplates. The rear wall of the hut will be left off for this purpose. The trunnions and reference prism mount will then be bolted to the baseplates and the autocollimator aligned in azimuth to the reference prism through the trunnion azimuth adjustment mechanism. The rear wall of the hut is then put in place and the installation of the LR2A is complete.

SECTION IV

TESTING

A. INTRODUCTION

In order to verify fulfillment of the LR2A performance requirements, Factory Acceptance tests will be performed at Perkin-Elmer.

All long range testing will be conducted outdoors to simulate as nearly as possible actual operating conditions. The horizontal line of sight, approximately six feet from the ground, will render all test results conservative due to the increased effects of atmospheric shimmer which appear as noise in the LR2A system. Since the LR2A will always operate at an elevation angle of approximately 30°, shimmer will be greatly reduced during the actual platform prism alignment.

B. TEST SEQUENCE

Four basic tests will be performed to prove satisfactory system performance.

1. Pointing Accuracy

This test will be conducted out of doors and will be designed to prove that a null is maintained when the line of sight is transferred from the reference prism to a parallel simulated missile prism located 500 feet from the LR2A. The null will be shown to repeat to within ±2 seconds. The laboratory test equipment used in conjunction with this test may introduce up to ±3 seconds of uncertainty which is not associated with LR2A operation. Therefore, to demonstrate ±2 seconds of system repeatability a ±5 seconds maximum observable error will be permissible.

The test procedure includes the following steps:

(1) Level end face of reference prism, using Kern DKM2 theodolite, to within ±1 minute.

(2) Level end face of simulated missile prism in similar manner.

(3) Move LR2A penta set to view reference prism.

(4) Adjust reference prism so that the LR2A will read null.

(5) Move penta set to view simulated missile prism which will be located at an operating distance of 500 feet. This prism will also be located so that a translation of approximately 6 inches is necessary to bring it into the field of view of the LR2A.

(6) Adjust simulated missile prism so that the LR2A will read null.

(7) Autocollimate Kern DKM2 theodolite to reference prism.

(8) Autocollimate Hilger-Watts TA-1 to flat mirror mounted on side of DKM2 theodolite.

(9) Move DKM2 theodolite approximately 6 inches and autocollimate it to simulated missile prism.

(10) Hilger-Watts TA-1 autocollimator should be autocollimated to flat mirror to within ±5 seconds.

2. Gain Calibration and Linearity

This test will also be conducted out of doors and will show that the calibrated gain adjustment LR2A will produce a constant gain for different operating distances between zero and 500 feet. Using the calibrated wedge provided with the instrument a linearity check will also be made between the limits of approximately ±15 seconds.

(1) Null reference prism to LR2A.

(2) Insert calibration wedge in front of reference prism and read angles marked on wedge (approximately ±15 seconds).

(3) Move simulated missile prism to 200 foot distance and set gain adjustment for 200 feet. Null micropositioner to LR2A.

(4) Insert calibration wedge and read error on Keithley DC meter. Reading should repeat to part 2 within ±20%.

(5) Move simulated missile prism to 400 feet and set gain adjustment to correspond. Repeat part 4. Indicated error again is to be within ±20% of part 2.

(6) Null instrument to prism at 500 feet. Take readings either side of null out of range of calibration wedge. Plot values obtained. All points should fall within ±20% absolute value lines.

3. Large Amplitude Sway Capability

Auxiliary equipment used to perform this test include both micro-positioner and Hilger-Watts autocollimator. This test equipment, used in an appropriate manner, may introduce uncertainty as large as ±2 seconds during this test run. Therefore, to demonstrate ±1 second of system performance, a ±3 second maximum observable error will be permissible. This test is intended to prove that the LR2A will maintain its null signal while transferring its line of sight to various positions within the 24-inch translational dynamic sway range. Since large operating distances are not necessary to prove this capability, the test will be performed indoors. A system error of less than ±1 second shall be shown to be present due to penta translations within the 24-inch range.

(1) Locate simulated missile prism near the left limit of penta travel.

(2) Adjust LR2A to read null.

(3) Autocollimate Hilger Watts to flat mirror mounted on the side of the reference prism.

(4) Move simulated missile prism 12 inches to right and move penta an equal amount. Re-null LR2A by adjusting simulated missile prism.

(5) Hilger Watts should be autocollimated to mirror mounted on side of missile prism.

(6) Move missile prism 12 more inches to right and repeat steps 4 and 5. Maximum observable error should be ±3 seconds.

C. TEST RESULTS

The following data was taken during factory acceptance testing of two LR2A instruments which were delivered to NASA. The results clearly indicate that the instruments met or exceeded all specifications.

TEST NO. 1

POINTING ACCURACY

Penta	Kern DKM2	Hilger Watts AC	LR2A Null Meter
Ref. Prism	0	13.2 sec.	0
500 Ft. Prism	0	13.2 sec.	+2 sec.
		Max. deviation	+2 sec.

Test Conducted by: W. Kokot W Kokot PECO
W. Zukowsky W. Zukowsky PECO

Test Witnessed by: H. Milde H. W. Milde NASA
J. Johnston ______ Brown Engineering

March 1, 1963

TEST NO. 2

500 FEET OPERATING DISTANCE

TIME CONSTANT 240 msec.

	Simulated Missile Prism Sec. Deviation	LR2A Meter (seconds)	Deviation
	0	+ 0 sec.	
CW	2	2	
	4	4	
	6	6	2 - 8 Sec.
	8	8	3 - 11
	10	10	5 - 12
	12	12	8 - 14
	14	13	10 - 14
	16	13-1/2	12 - 14
	18	13-1/2	- 14-1/2
	20	+14	14-1/2
CCW	2	- 2	0 - 4-1/2
	4	4-1/2	2-1/2 - 6-1/2
	6	6	2-1/2 -10
	8	8	3-11
	10	10	7-13
	12	11-1/2	10-13-1/2
	14	13	10-1/2 - 14-1/2
	16	13-1/2	12-1/2 - 14-1/2
	18	14	13-1/2 - 14-1/2
	20	-14	- 14-1/2

Test Conducted by: W. Kokot *W. Kokot* PECO
W. Zukowsky *W. Zukowsky* PECO

Test Witnessed by: H. Milde *H. H. Milde* NASA
J. Johnston ________ Brown Engineering

TEST NO. 2

400 FEET OPERATING DISTANCE

TIME CONSTANT 240 msec.

Simulated Missile Prism Sec. Deviation	LR2A Meter (seconds)	Deviation
CW 2 Sec.	+ 2	-1/2 - 3-1/2
4	4	1 - 6-1/2
6	6	1-1/2 - 9
8	8	5-1/2 - 11
10	10	7-1/2 - 12-1/2
12	12	9 - 14
14	13	10-1/2 - 14-1/2
16	14	10-1/2 - 15
18	14-1/2	13-1/2 - 15
CW 20	+ 15	14-1/2 - 15
CCW 2	- 2	0 - 5
4	4-1/2	3 - 7
6	6-1/2	4-1/2 - 9-1/2
8	8-1/2	6 - 12
10	10	8 - 13
12	12	10 - 14
14	13-1/2	12-1/2 - 14-1/2
16	14-1/2	14-15
18	15	-15
CCW 20	- 15	-15

Test Conducted by: W. Kokot *W. Kokot* PECO
W. Zukowsky *W. Zukowsky* PECO

Test Witnessed by: H. Milde *H. W. Milde* NASA
J. Johnston ______ Brown Engineering

TEST NO. 2

400 FEET OPERATING DISTANCE

TIME CONSTANT 1440 ~~msec~~.

Simulated Missile Prism Sec. Deviation		LR2A Meter (seconds)	Deviation
CW	2 Sec.	+2 sec.	0-3-1/2
	4	4	3-5-1/2
	6	6-1/2	4-8
	8	8-1/2	7-10
	10	10	9-1/2 - 10-1/2
	12	11-1/2	10-1/2 - 12
	14	13	12 - 14
	16	14	13-1/2 - 14-1/2
	18	14-3/4	---
CW	20	+14-3/4	
CCW	2	-2	1/2 - 3-1/2
	4	4-1/2	3-1/2 - 5-1/2
	6	6-1/2	5-1/2 - 7-1/2
	8	8	6-1/2 - 9
	10	10	9 - 11-1/2
	12	11-1/2	10-12-1/2
	14	12-1/2	11-1/2 - 13-1/2
	16	13-1/2	13-14
	18	14	13-1/2 -
	20	-14	14

Test Conducted by: W. Kokot *W. Kokot* PECO
W. Zukowsky *W. Zukowsky* PECO

Test Witnessed by: H. Milde *H. Milde* NASA
J. Johnston ______ Brown Engineering

TEST NO. 3

LARGE AMPLITUDE SWAY CAPABILITY

Penta Position	LR2A Null Meter	Hilger Watts Autocollimator
0 (Right)	0	21.4
12" (Center)	0	20.5
24" (Left)	0	20.5
		Max. Deviation = .9 second

Test Conducted by:	W. Kokot	W. Kokot	PECO
	W. Zukowsky	W. Zukowsky	PECO
	T. Havel	[illegible]	PECO
Test Witnessed by:	H. Milde	H. W. Milde	NASA
	J. Johnston		Brown Eng.

TEST NO. 4

DYNAMIC (SMALL AMPLITUDE) SWAY CAPABILITY

Micropositioner Position	LR2A Null Meter	Hilger Watts Autocollimator
0	0	20.8
- 2½ inches	0	22.6
+ 2½ inches	0	21.1
		Max. Deviation = 1.8 seconds

Test Conducted by: W. Kokot W. Kokot PECO

W. Zukowsky W. Zukowsky PECO

T. Havel T. H. PECO

Test Witnessed by: H. Milde H. W. Milde NASA

J. Johnston ______ Brown Eng.

TEST NO. 3

LARGE AMPLITUDE SWAY CAPABILITY

Penta Position	LR2A Null Meter (Sec.)	Hilger Watts Autocollimator (Sec.)
Center	0	5.0
12" Full Right	0	7.2
12" Full Left	0	5.6
		2.2 Sec.
24" Total Penta Travel		

Test Conducted by: W. Kokot *W. Kokot* PECO

W. Zukowsky *W. Zukowsky* PECO

T. Havel *T. Havel* PECO

Test Witnessed by: K. Clark *K. Clark* NASA

Brown Eng.

TEST NO. 4

DYNAMIC (SMALL AMPLITUDE) SWAY CAPABILITY

Micropositioner Position	LR2A Null Meter (Sec.)	Hilger/Watts Autocollimator (Sec.)
+ 2-1/2" Right	0	3.4
0 Center	0	4.8
- 2-1/2 Left	0	5.0
		1.6 Sec. Max. Deviation

Test Conducted by: W. Kokot *W. Kokot* PECO

W. Zukowsky *W. Zukowsky* PECO

T. Havel *T. Havel* PECO

Test Witnessed by: Keith Clark *K. Clark* NASA

Brown Eng.

TEST NO. 2

500 FEET

TIME CONSTANT - 2570 msec.

Simulated Missile Prism Sec. Deviation	LR2A Meter (seconds)	Deviation
0	0	-2, +1-1/2
4 Sec CW	+ 4	+2, +7
7 Sec. CW	+7	+5, +12
11 Sec. CW	+11	+8, +13
Return to 0	-1/2 Sec.	-2-1/2, +2
Nulled 0	0	
-4 Sec. CCW	-4	-1-1/2, -6-1/2
-7 Sec. CCW	-6-1/2	-5, -10
-11 Sec. CCW	-10	-7-1/2, -12-1/2

Test Conducted by: W. Kokot *W. Kokot* PECO
W. Zukowsky *W. Zukowsky* PECO

Test Witnessed by: K. Clark *K. Clark* NASA
Brown Engineering

TEST NO. 2

300 FEET

TIME CONSTANT -2570 msec.

Simulated Missile Prism Sec. Deviation	LR2A Meter (seconds)	Deviation
0	0	-2, +1-1/2
5 Sec. CW	+4-1/2	+3, +6-1/2
8 Sec. CW	+[illegible]-1/2	+5, +9
11 Sec. CW	+10 Sec.	+9, +11
Return to Null (0)	(0)	-2-1/2, +2
3 Sec.	2-3/4	-1, -6
7	7-1/2	-4, -9
11	11-3/4	-10, -14

Test Conducted by: W. Kokot *W. Kokot* PECO
W. Zukowsky *W Zukowsky* PECO

Test Witnessed by: K. Clark *K Clark* NASA
Brown Engineering

TEST NO. 1

POINTING ACCURACY

Penta	Kern DKM2	Hilger Watts AC	LR2A Null Meter
500 Ft. Prism	0	8.1 Sec.	Null
Ref. Prism	0	10.2 Sec.	Null
	Deviation =	2.1 Sec.	

REPEAT TEST

Ref. Prism	0	15.4	Null
500 Ft. Prism	0	14.7	Null
	Deviation =	0.7 Sec.	

Test Conducted by: W. Kokot *W. Kokot* PECO
W Zukowsky *W Zukowsky* PECO

Test Witnessed by K. Clark *K Clark* NASA
Brown Engineering

MODIFICATIONS

During development and testing of the LR2A instruments certain modifications were found to be desirable. These modifications will be incorporated into the design of any additional LR2A instruments built in the future.

A. OPTO-MECHANICAL CONSIDERATIONS

(1) The included angle between the sides of the sensing prism should be changed to 90° from the present 72°. This will greatly reduce spillover light on to the error channel detectors and eliminate the need for a re-imaging system behind the nose of the sensing prism.

(2) Provide mechanical masking for the sensing prism so as to assure equal image heights for both phases of light incident on the prism. The amount of scattered light in the source detector area will also be greatly reduced.

(3) Provide a four point support for positioning of source condenser mirror. This will eliminate azimuth to elevation cross-coupling inherent in adjustment of the 3 point support now in use.

(4) Provide a means of adjustment for positioning the acquisition detector during final autocollimator alignment.

(5) Mount the chopper motor to the base plate in the source-detector housing instead of to a bridge plate located above the optical elements. This will allow for easy access to the source detector elements during final alignment. The present scheme requires removal of chopper motor and blades in order to accomplish practically all adjustments.

(6) Use Ni Resist-5 (Minivar) more extensively in the source detector area to preclude the possibility of movement of optical elements during very large temperature changes.

(7) Provide better means of adjustment for positioning the phase sensing photo-transistor.

(8) Revise optical design to incorporate the use of a parabolic primary mirror and plane parallel front window to replace the spherical primary mirror and aspherized Maksuton corrector shell. As a result of our experience with the manufacture of the aspheric Maksuton shell, a parabolic primary appears to be a simpler, less costly solution for an autocollimator of this type with no degradation of image quality.

(9) Improve design of penta linear actuator drive mechanism to provide slower, smoother, and quieter action. Also provide for more positive limit stops.

(10) Increase flexability of cables leading from pre-amplifier housing to junction box.

B. ELECTRONIC CONSIDERATIONS

(1) Replace the present lamp power transformer with a multi-tap transformer. This will provide a better means of controlling lamp intensity and/or life.

(2) Reduce collector current in the d.c. differential output amplifier. This will result in improved stability when transistor replacement is necessary.

(3) Redesign preamplifier package to improve servicing and accessability.

(4) Replace ring demodulators with transistor demodulators. This will result in fewer components, better reliability and space reduction.

(5) Improve the isolation between the acquisition and error channels by including a blocking tunnel rectifier.

C. ALIGNMENT OF A SECOND PRISM

Changes in the Saturn guidance system and laying procedure require added alignment capability and more fully automatic operations of the LR2A. The necessary modifications are under development on one instrument to be known as the LR2A/GS.

One modification provides a means of determining parallel azimuth orientation of the stabilized guidance system platform with respect to an added prism on the azimuth gimbal. Since it is necessary to view both prisms with the same theodolite the optical signals must be separated and distributed to their respective detectors to avoid cross coupling. Perkin-Elmer has chosen to use spectral separation to discriminate between the two returned optical signals.

The output signal characteristics of the second channel will duplicate those from the first described above.

D. AUTOMIC SWAY TRACKING

The other modification will include provisions to automatically maintain the long range theodolite line of sight centered on the guidance system prisms as the space booster sways. A sway sensor together with a servo loop will continuously monitor the target prism and reposition the movable penta mirror assembly.

The method of sway sensing employed is based on advanced techniques proprietary to Perkin-Elmer. These techniques are capable of providing the desired performance in a simple and direct manner. The method makes use of information in the present optical signals and requires no additional components on the space booster. The portion of the LR2A pupil through which the light reflected from the platform prism returns is sensed and appropriate electronic action in conjunction with the servo loop repositions the penta mirror assembly to the center of the platform prims's line of sight.

SECTION VI

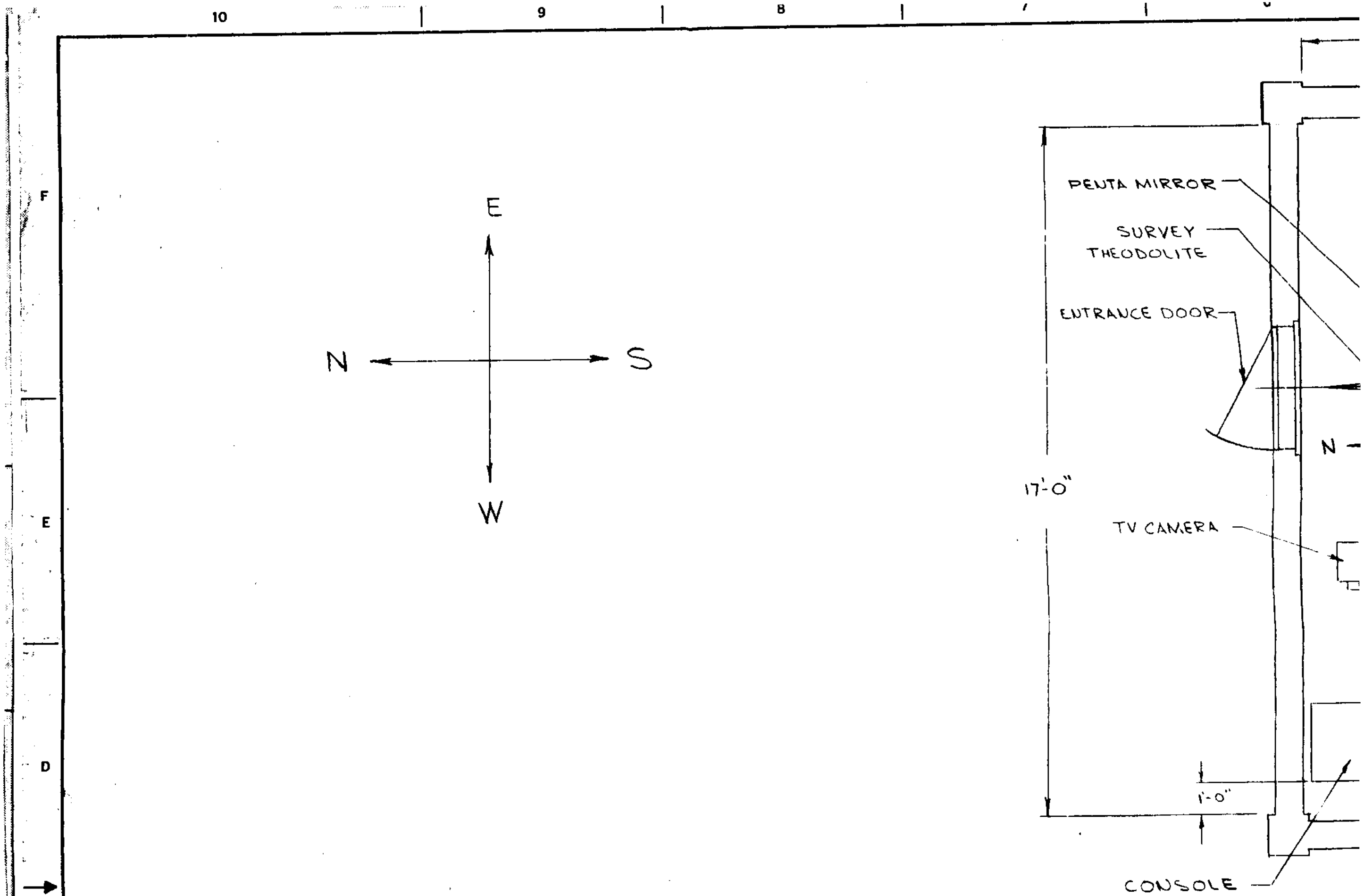
SUMMARY

27268

ABSTRACT:

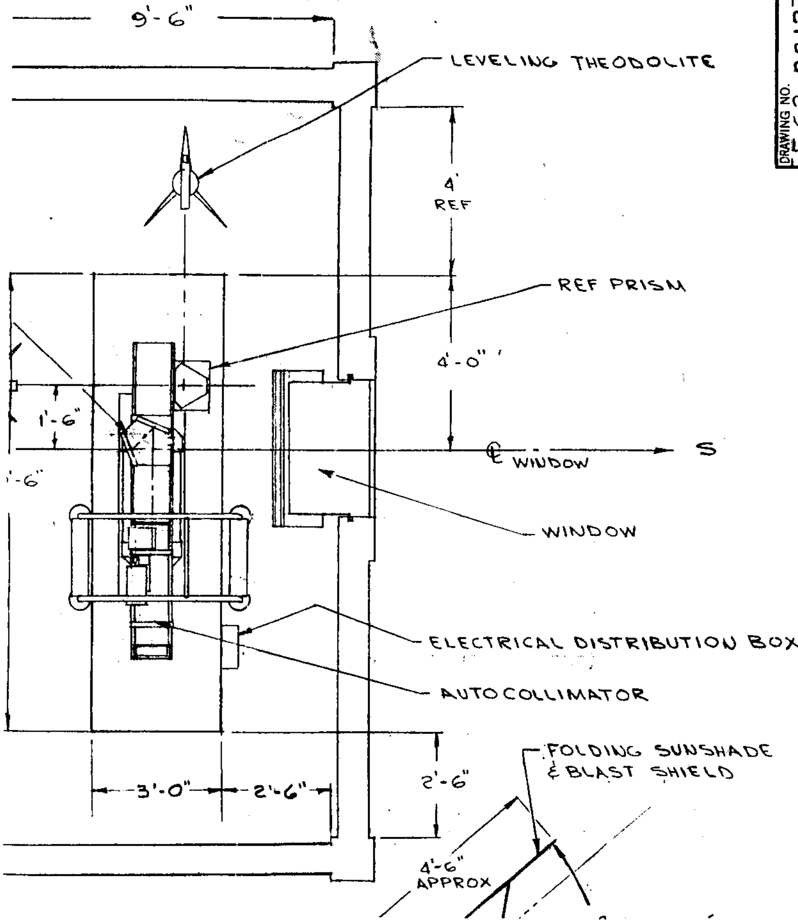
The Saturn LR2A theodolite constitutes an excellent solution to the azimuth laying problem of large space boosters. Operating at distances up to 1000 feet, it provides extreme angle sensing accuracy in the presence of up to ±12 inches of dynamic and static booster sway, and any amount of sag during fueling. In its present configuration it permits fully remote operation by operator reference to two TV camera displays. A new LR2A/GS version currently under development incorporates alignment capability for a second prism and, by the addition of automatic sway tracking, operates essentially unattended. In either case the LR2A instrumentation is quite simple and basic, consisting primarily of static elements, and possesses excellent reliability (computed). Its extremely flexible design permits easy adaptation to a wide variety of alignment assignments.

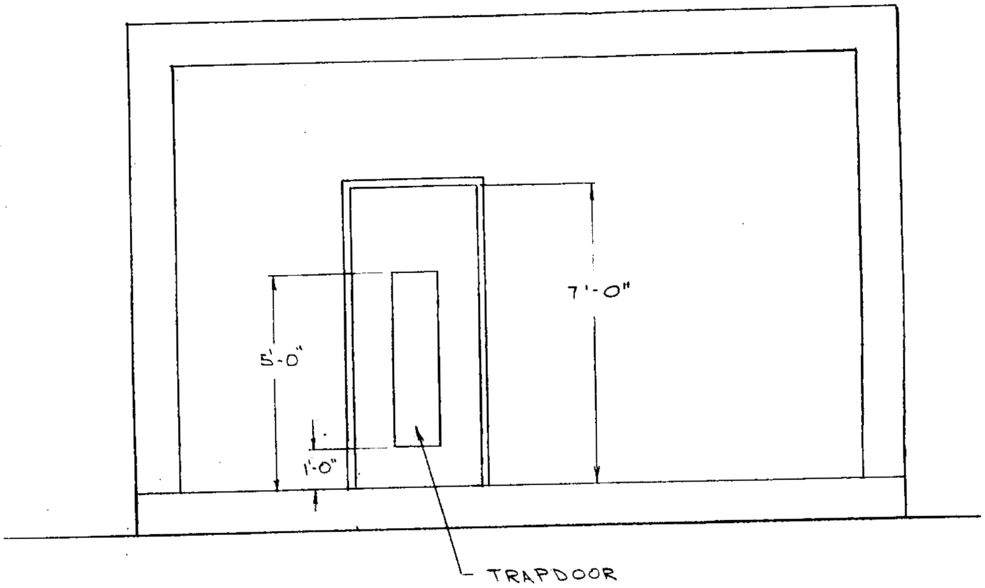
AUTHOR:


10
9
8
7
F
E
D
E
N
S
W
PENTA MIRROR
SURVEY
THEODOLITE
ENTRANCE DOOR
N
17'-0"
TV CAMERA
1'-0"
CONSOLE

DRAWING NO. 563-0012

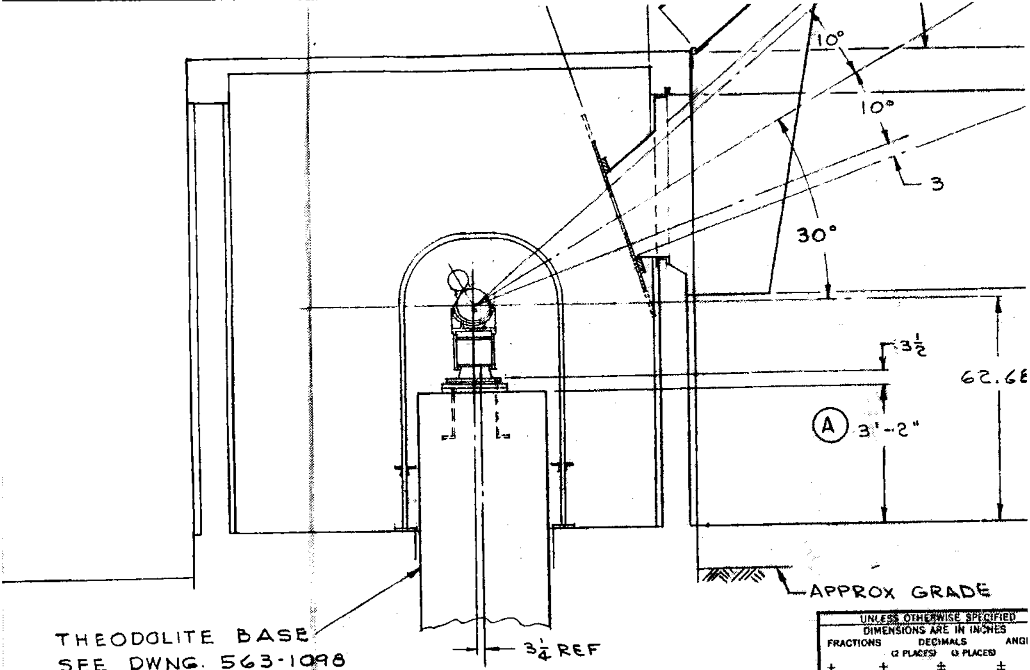
REVISIONS			
SYM	DESCRIPTION	DATE	APPROVED
A	CONCRETE PIER WAS 2'-3" NOW 3'-2"	9-7-62	VK
B	THEOD. REDRAWN TO SCALE	10-16-62	[illegible]
	ELEC. DISTRIBUTION BOX MOVED		
	DWNG. NO. WAS 563-1097		





NOTE:
1. SEE SHEET 2 FOR DETAIL ON WINDOW & FOLDING SUNSHADE

C
B
A
10
9
8
7



UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES

FRACTIONS	DECIMALS (2 PLACES)	DECIMALS (3 PLACES)	ANGI
±	±	±	±

SHARP CORNERS TO BE BROKEN TO .005 MAX.
ALL DIAMETERS ON SAME AXIS, CONCENTRIC WI
.006 T. I. R.

ALL √ SURFACES TO BE √

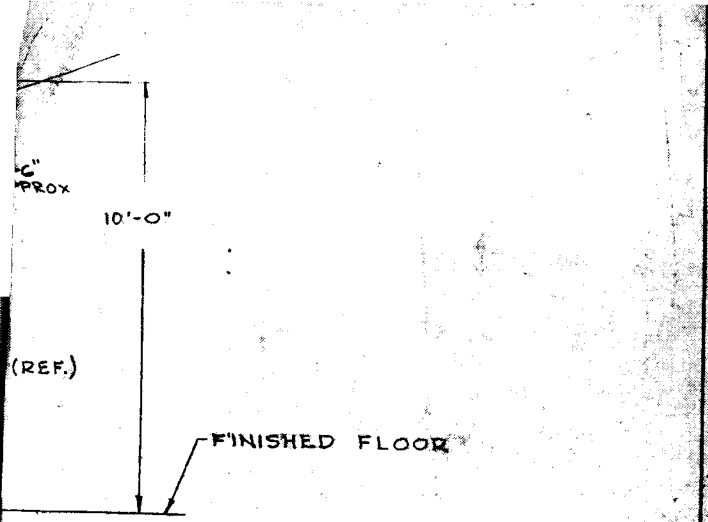
ALL DIMENSIONS AND TOLERANCES APPLY BEFORE FINISH TREATMENT.

MATERIAL

FINISH

NEXT ASSEMBLY	QUANTITY

6 5 4 3



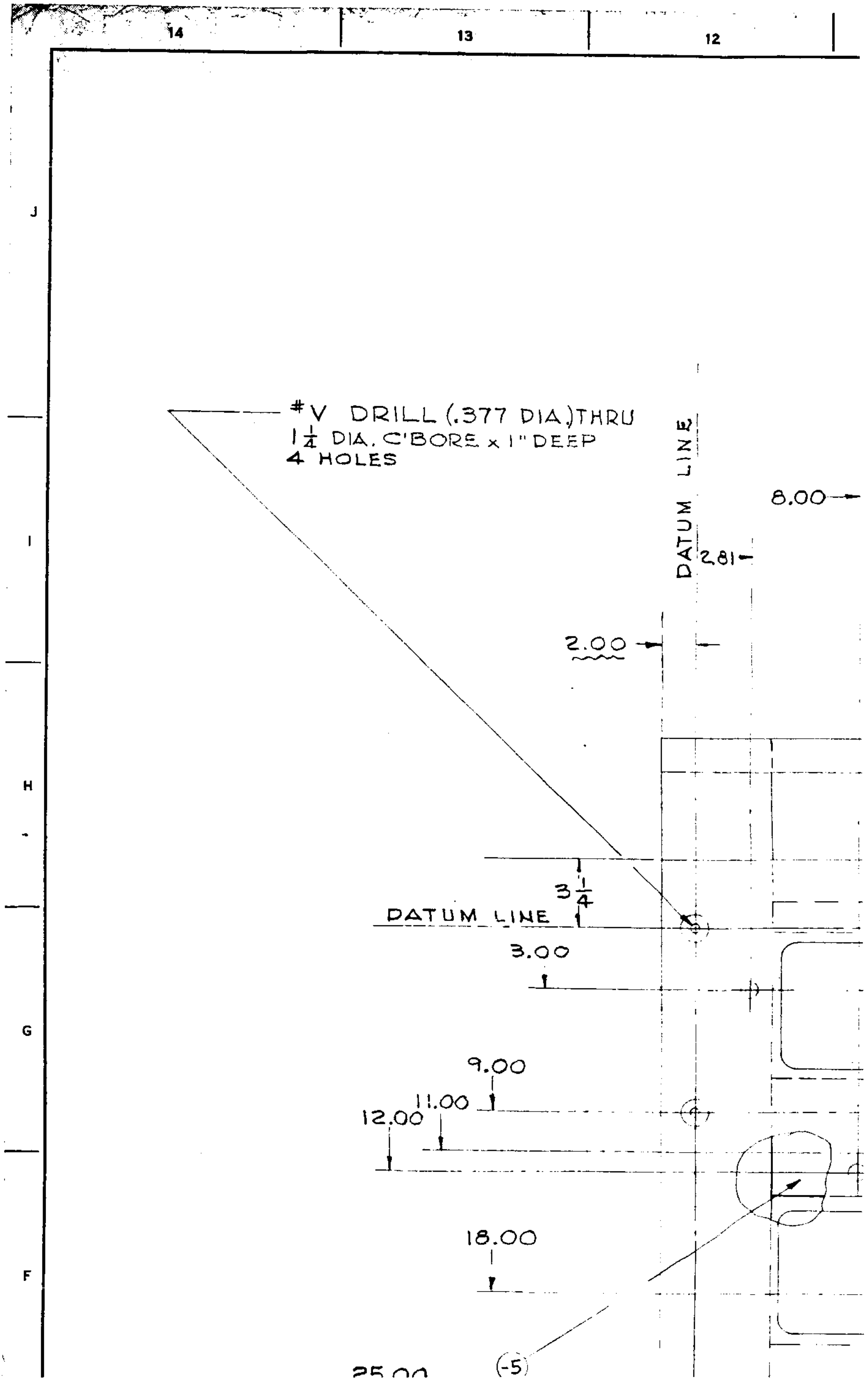
ORIGINAL DATE OF DRAWING	8-17-62
DRAFTSMAN	A Avanzato
CHECKER	S. B. Fuel 11-28-62
APPROVED	
APPROVED	
APPROVED	N. Kokot
DES. APPROVAL	J. Zeller 11-28-62
STDS. APPROVAL	R Hobe 11-28-62

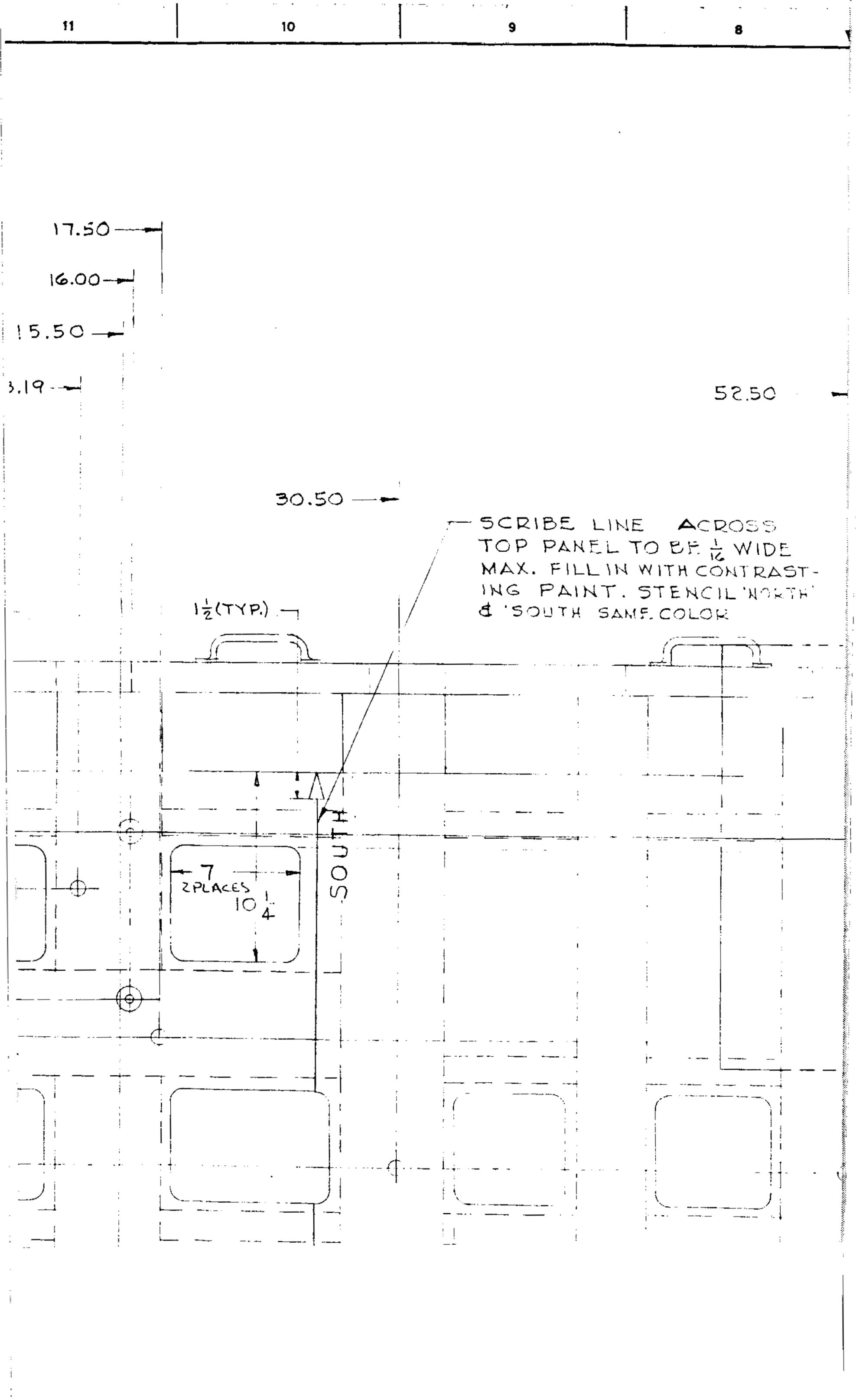
PE. ELECTRO-OPTICAL DIVISION
Perkin-Elmer Corporation
NORWALK, CONNECTICUT

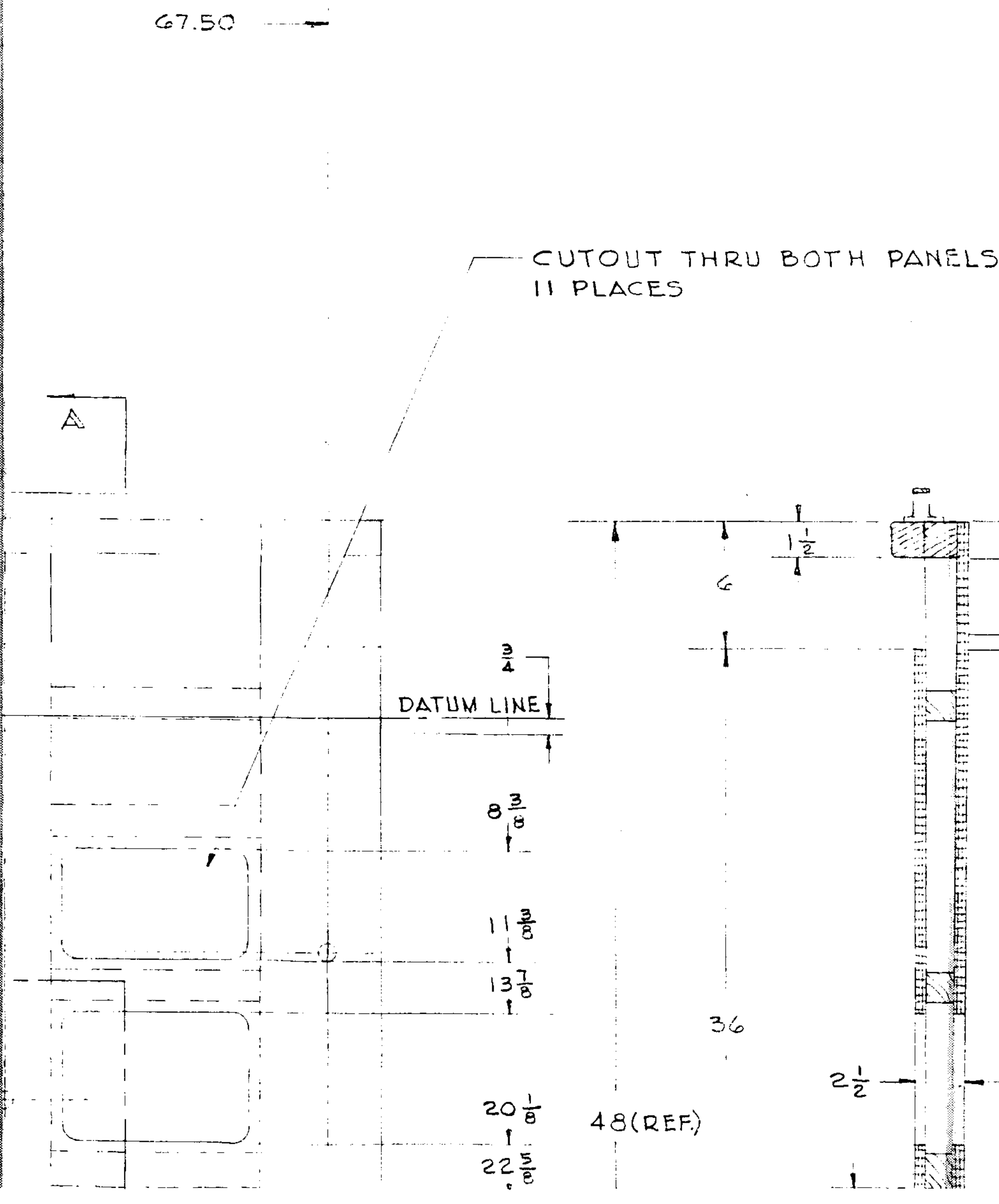
HUT LAYOUT —
SATURN THEODOLITE

CODE IDENT NO.		
46555	D	563-0012

SCALE 1/2" = 1'-0" WT SHEET 1 OF 2


14
13
12
J
I
H
G
F
#V DRILL (.377 DIA.) THRU
1 1/4 DIA. C'BORE x 1" DEEP
4 HOLES
DATUM LINE
8.00
2.81
2.00
3 1/4
DATUM LINE
3.00
9.00
11.00
12.00
18.00
(-5)


11
10
9
8
17.50
16.00
15.50
.19
52.50
30.50
SCRIBE LINE ACROSS TOP PANEL TO BE 1/16 WIDE MAX. FILL IN WITH CONTRASTING PAINT. STENCIL 'NORTH' & 'SOUTH' SAME COLOR
1½(TYP.)
7
2PLACES
10 1/4
SOUTH


67.50
CUTOUT THRU BOTH PANELS
11 PLACES
A
DATUM LINE
3/4
1 1/2
6
8 3/8
11 3/8
13 7/8
36
2 1/2
20 1/8
48(REF.)
22 5/8

3 2 1

REVISIONS			
SYM	DESCRIPTION	DATE	APPROVED
B	REDESIGNED AND REDRAWN ECN 10236	9-19-62	W.K

J

I

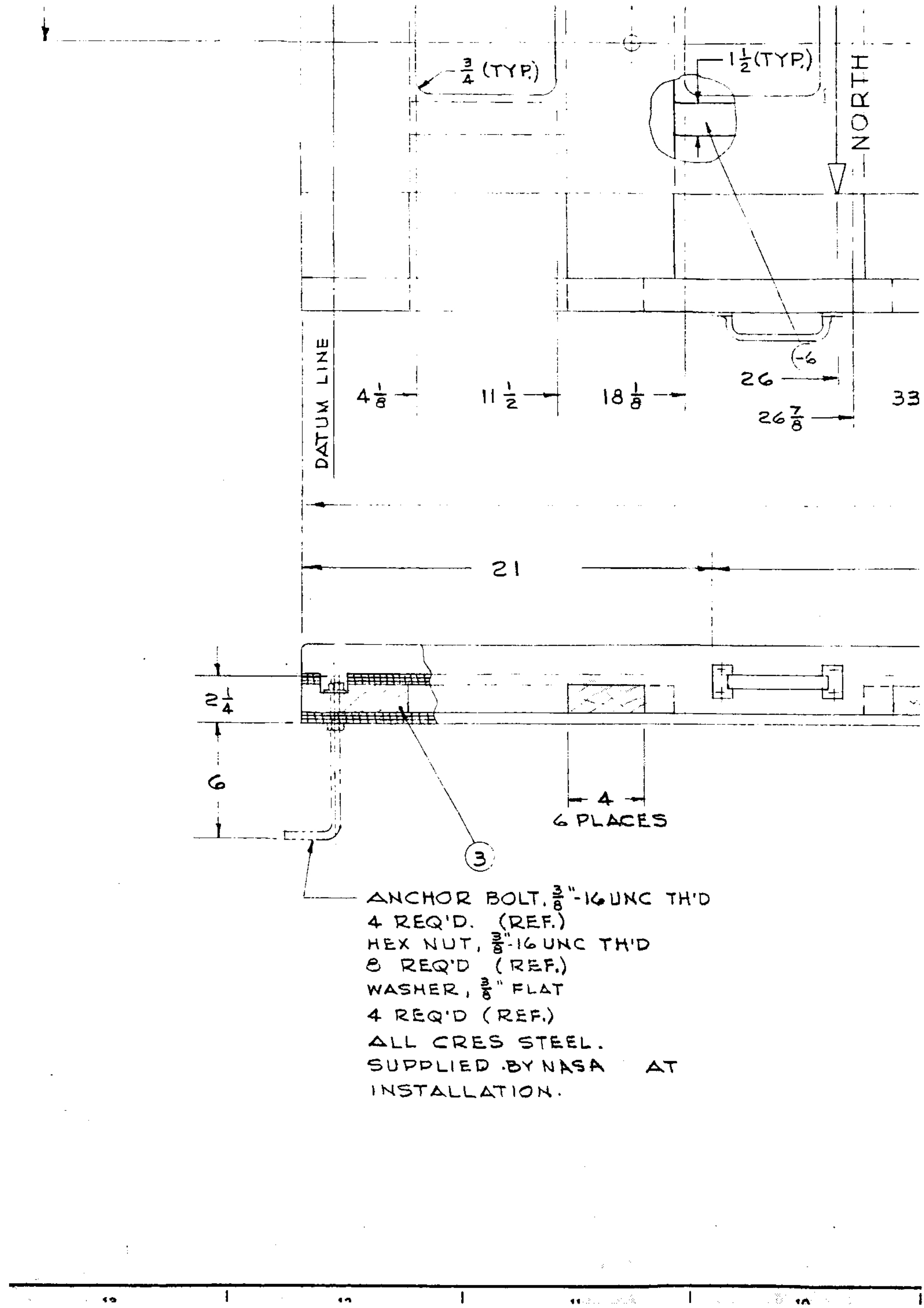
H

G

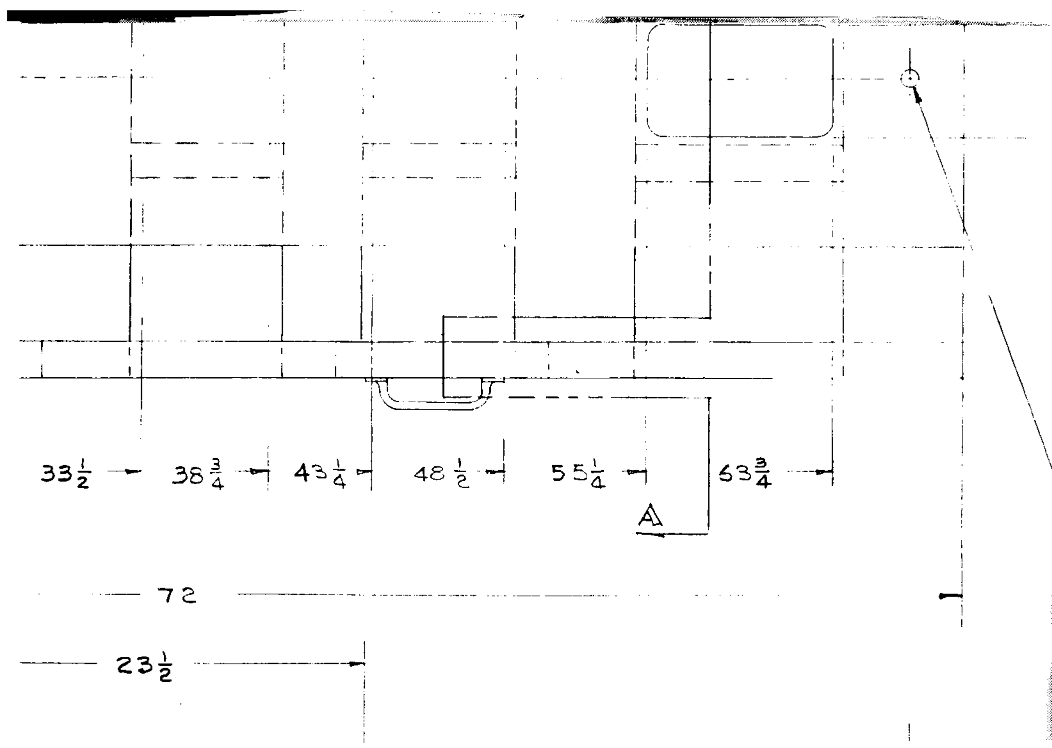
FORM FOR CONC. FOUNDATION
SHOWN IN PHANTOM

-2

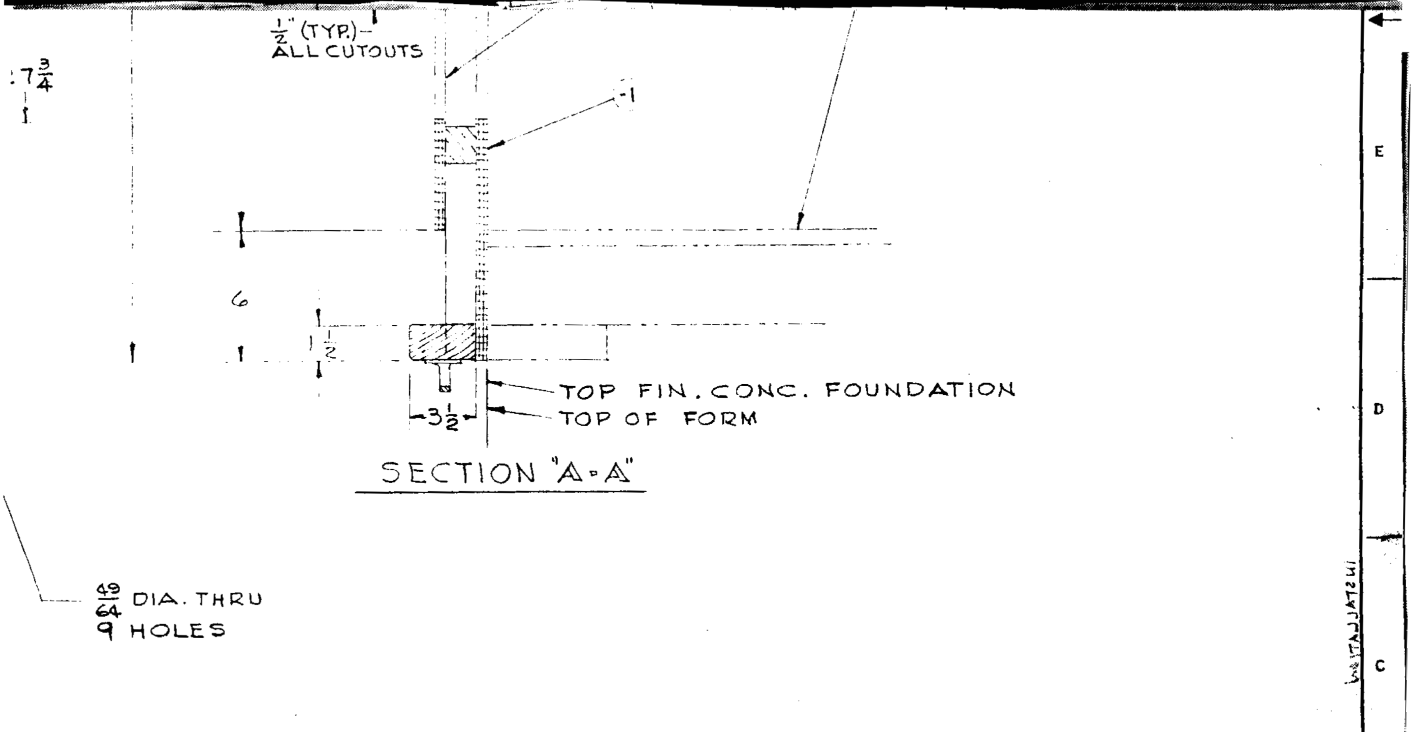
F



3/4 (TYP.)
1 1/2 (TYP.)
NORTH
DATUM LINE
(-6
4 1/8
11 1/2
18 1/8
26
26 7/8
33
21
2 1/4
6
4
6 PLACES
3
ANCHOR BOLT, 3/8"-16 UNC TH'D
4 REQ'D. (REF.)
HEX NUT, 3/8"-16 UNC TH'D
8 REQ'D (REF.)
WASHER, 3/8" FLAT
4 REQ'D (REF.)
ALL CRES STEEL.
SUPPLIED BY NASA AT
INSTALLATION.

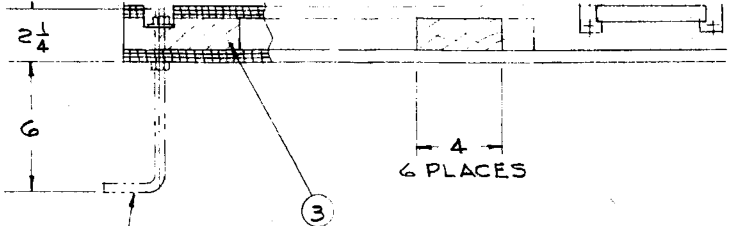


33 1/2
38 3/4
43 1/4
48 1/2
55 1/4
63 3/4
A
72
23 1/2



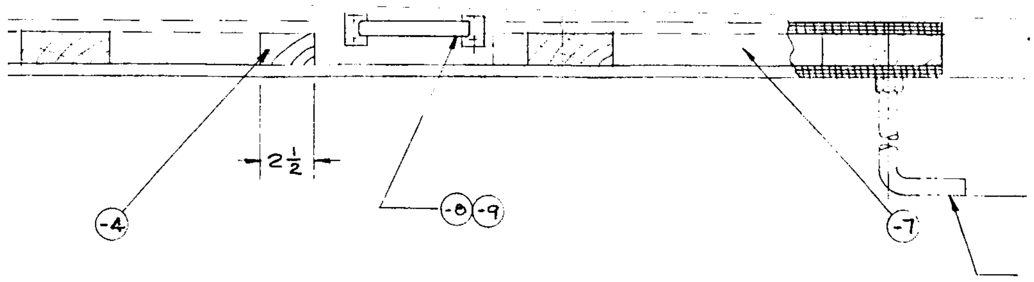
$\frac{1}{2}$" (TYP.) ALL CUTOUTS
$7\frac{3}{4}$
-1
6
$\frac{1}{2}$
$3\frac{1}{2}$
TOP FIN. CONC. FOUNDATION
TOP OF FORM
$\frac{49}{64}$ DIA. THRU
9 HOLES
E
D
C

SECTION "A-A"



ANCHOR BOLT, $\frac{3}{8}$"-16 UNC TH'D
4 REQ'D. (REF.)
HEX NUT, $\frac{3}{8}$"-16 UNC TH'D
8 REQ'D (REF.)
WASHER, $\frac{3}{8}$" FLAT
4 REQ'D (REF.)
ALL CRES STEEL.
SUPPLIED BY NASA AT
INSTALLATION.

13 | 12 | 11 | 10



2. SIZE OF PARTS -3, -4, -5, -6, AND METHOD OF FRAMING OPTIONAL
1. SINGLE END DIMENSIONS ARE MEASURED FROM DATUM LINE.

NOTES -

$3\frac{1}{2}$

12

ANCHOR BOLT, $\frac{3}{4}$"-10 UNC TH'D
9 REQ'D. (REF.)
HEX NUT, $\frac{3}{4}$"-10 UNC TH'D
18 REQ'D (REF.)
WASHER - $\frac{3}{4}$" HEAVY FLAT
9 REQ'D (REF.)
ALL CRES STEEL.
SUPPLIED BY NASA AT
INSTALLATION

DRAWING NO. 563-1194

REV. LET. A

ITEM NO.	PART NUMBER	DESCRIPTION	QTY REQD	MATERIAL	SPEC.	UNIT WT.	CODE IDENT
-9	COM'L	WOOD SCREW	16				
-8	COM'L	HANDLE	4				
-7		STRINGER	2	WHITE PINE			
-6		BLOCK, $1\frac{1}{2}$ WIDE	19	WHITE PINE			
-5		BLOCK, $5\frac{5}{8}$ WIDE	1				
-4		CROSS RAIL, 3 [illegible] WIDE x 4'-0 LONG	1				
-3		CROSS RAIL, 5 [illegible] WIDE x 4' LONG	5	WHITE PINE			
-2		PANEL, TOP	1	½" MARINE PLYWOOD			
-1		PANEL, BOTTOM	1	½" MARINE PLYWOOD			

LIST OF MATERIALS

NEXT ASSEMBLY	QUANTITY
563-0010	1

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
FRACTIONS ± $\frac{1}{16}$ DECIMALS (2 PLACES) ±.015 (3 PLACES) ± — ANGLES ± —
SHARP CORNERS TO BE BROKEN TO .005 MAX. RAD. ALL DIAMETERS ON SAME AXIS, CONCENTRIC WITHIN .006 T.I.R.
ALL √ SURFACES TO BE √
ALL DIMENSIONS AND TOLERANCES APPLY BEFORE FINISH TREATMENT.
MATERIAL AS NOTED
FINISH

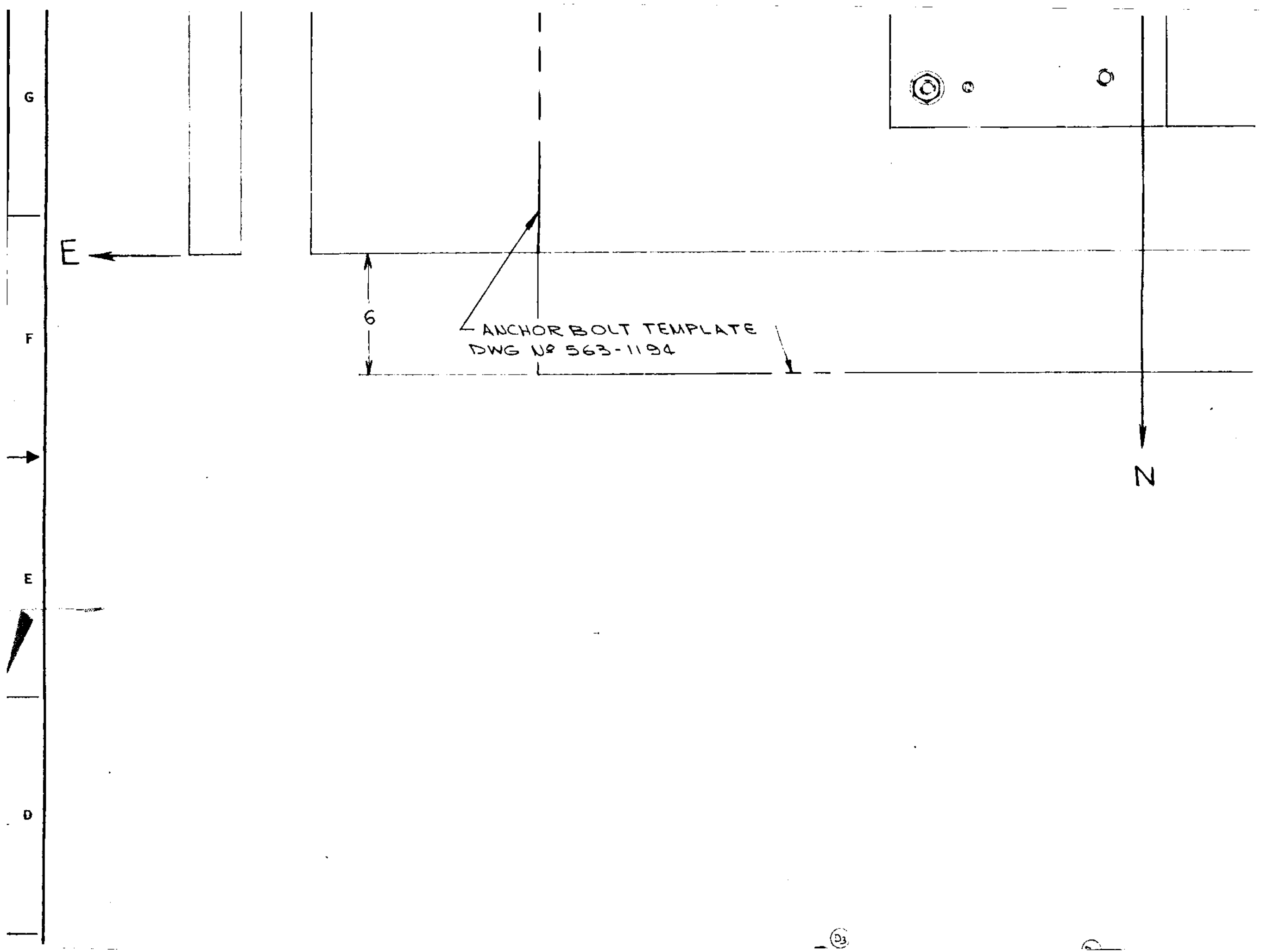
ORIGINAL DATE OF DRAWING 8-16-62
DRAFTSMAN A. AVANZATO
CHECKER S. B. Fick 8-21-62
APPROVED
APPROVED
APPROVED W. Kokot
DES. APPROVAL [illegible]
STDS. APPROVAL [illegible]

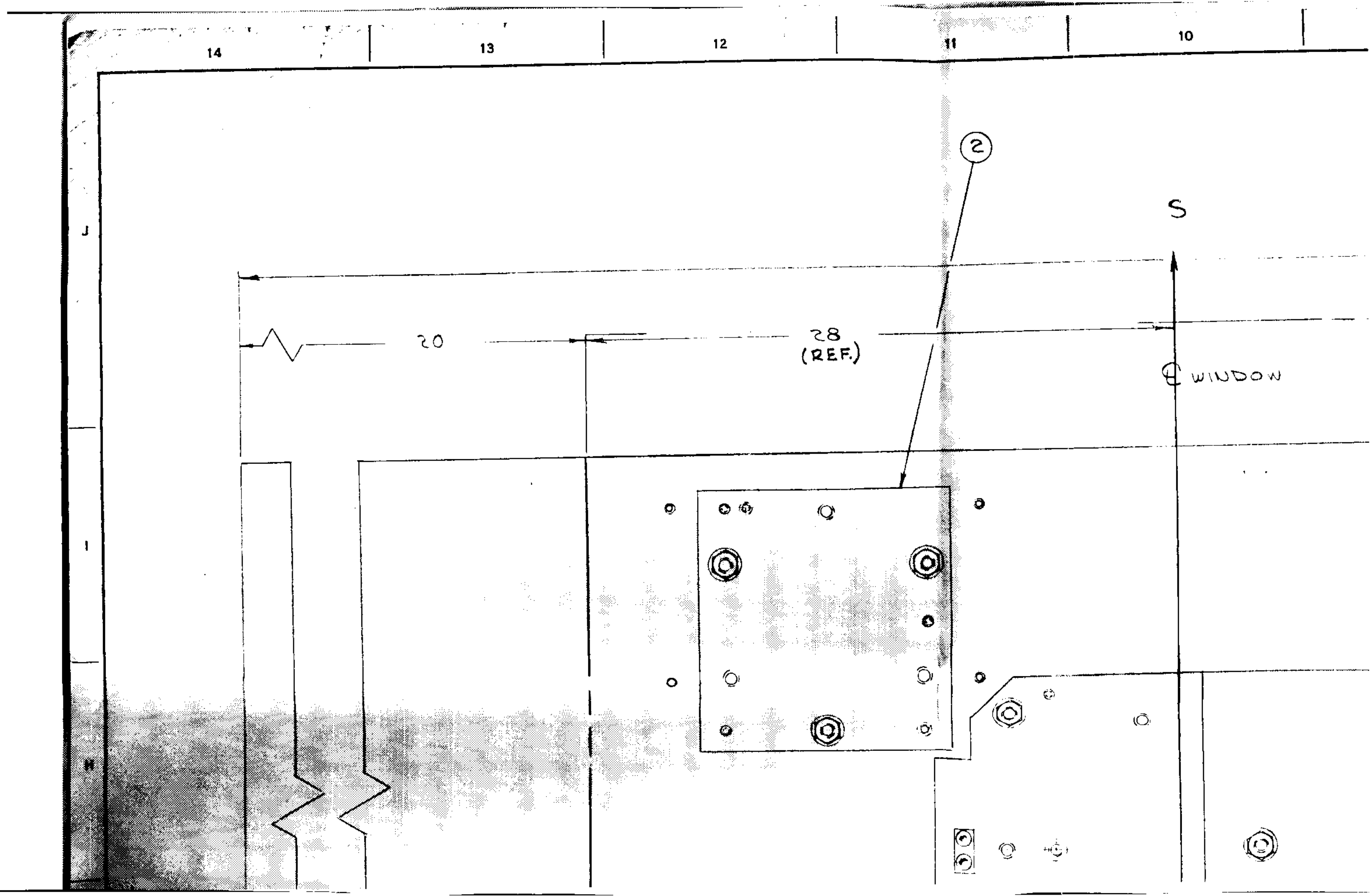
ELECTRO-OPTICAL DIVISION
Perkin-Elmer Corporation
NORWALK, CONNECTICUT

TEMPLATE, ANCHOR BOLT
SATURN THEODOLITE

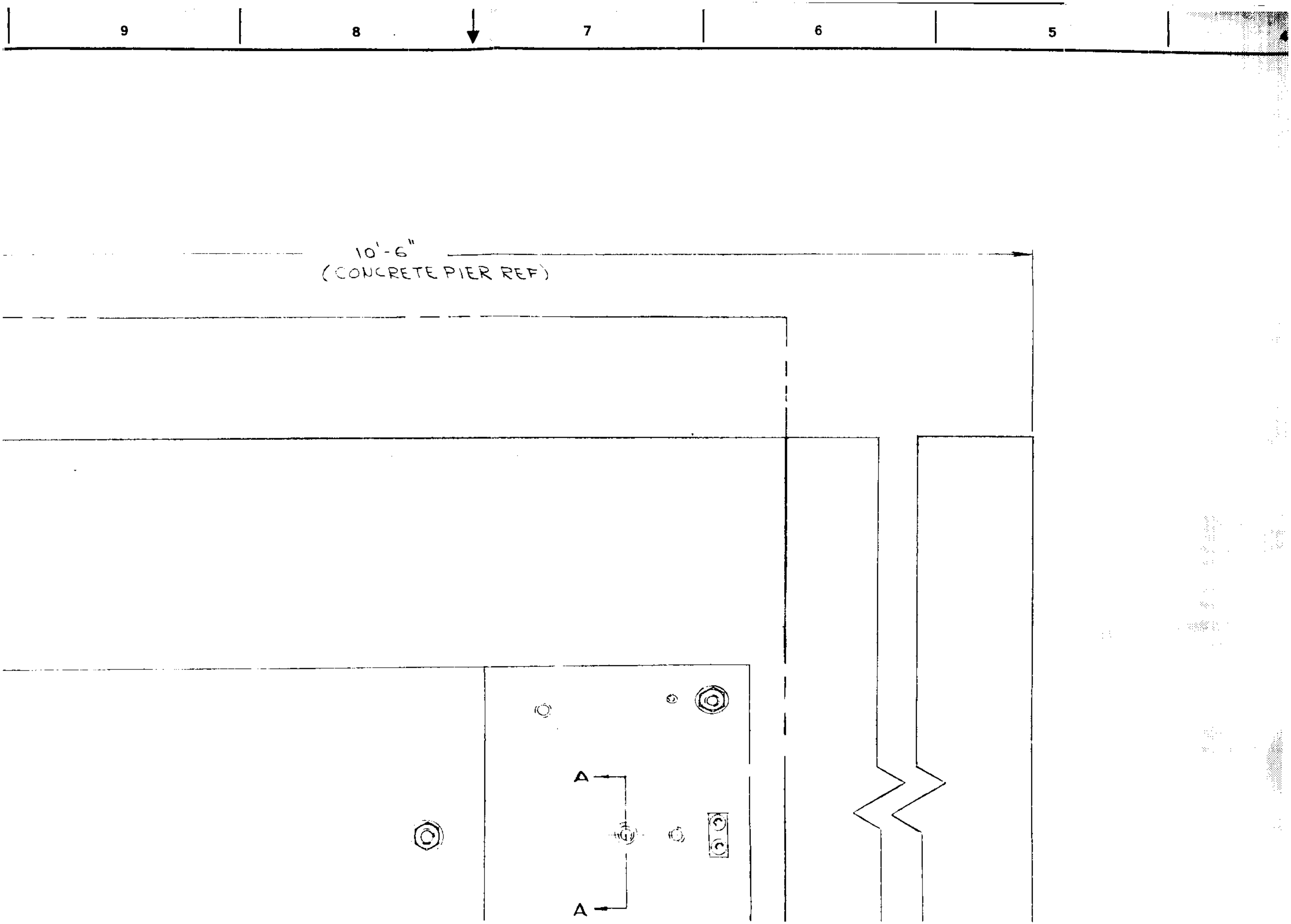
CODE IDENT NO. 46555 E 563-1194

SCALE 1/4 WT SHEET


E
6
ANCHOR BOLT TEMPLATE
DWG Nº 563-1194
N
G
F
E
D



14
13
12
11
10
J
I
H
2
S
20
28
(REF.)
℄ WINDOW



9
8
7
6
5
10'-6"
(CONCRETE PIER REF)
A
A

3 2 1

REVISIONS

SYM	ZONE	DESCRIPTION	DATE	APPROVED
A		CONCRETE PIER WAS 3'-3' NOW 3'-2"	9-7-62	WK
B		REDRAWN - L/M ADDED	9-13-62	WK
C		DWNG NO. WAS 563-1098. DWNG REVISED TO BECOME "REFERENCE ONLY"	11-26-62	S.D.F.
D	C7, C10, C11	D1 D2 D3 ADD LETTERS A & B ECN 10250	11-29-62	W.K.
	A6, A7	D4 D5 ADD. LEVELING INFORM.		
	E4	D6 SOC. SET. SCR. WAS SOC. CAP SCR		

J

I

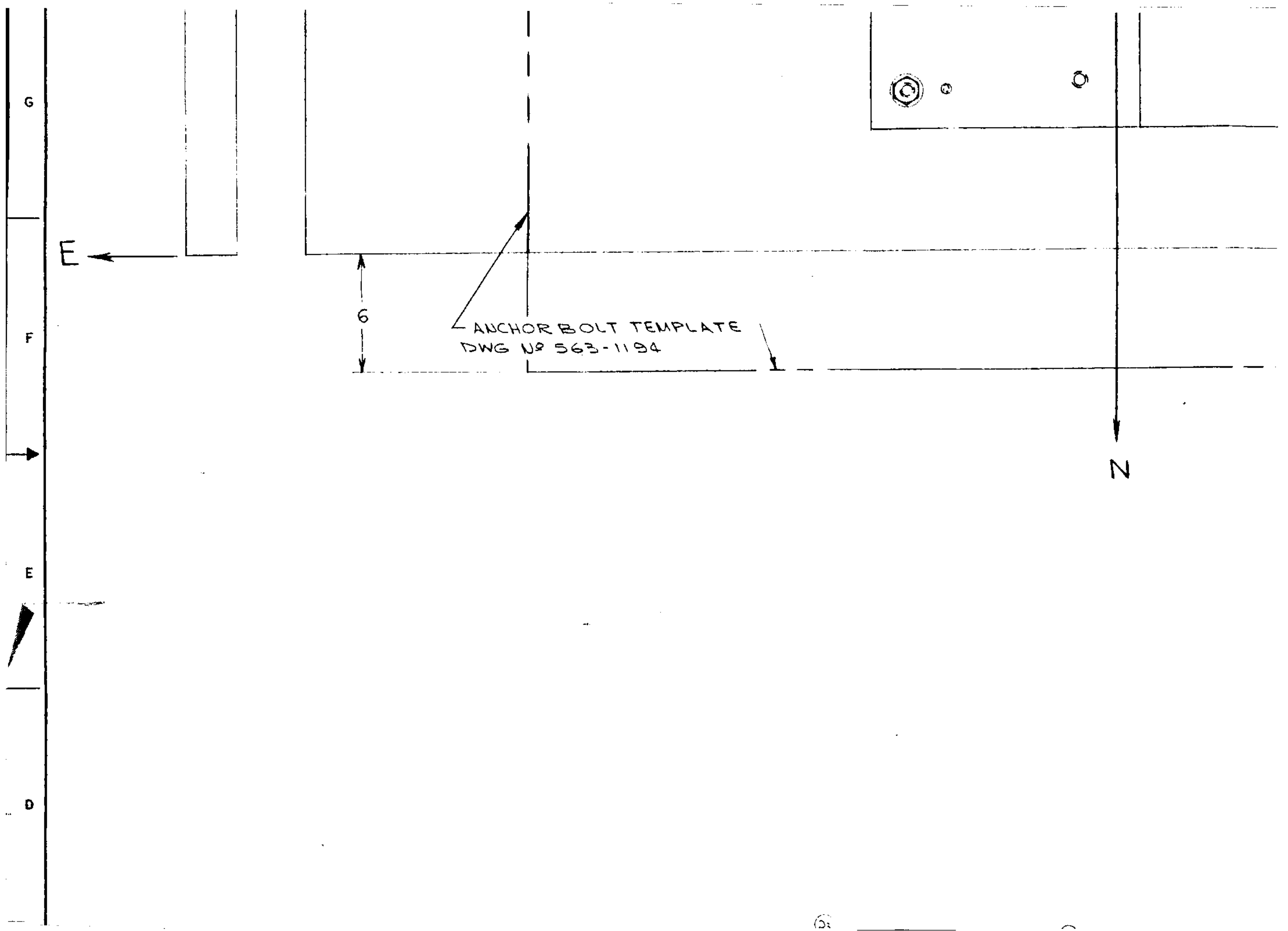
H

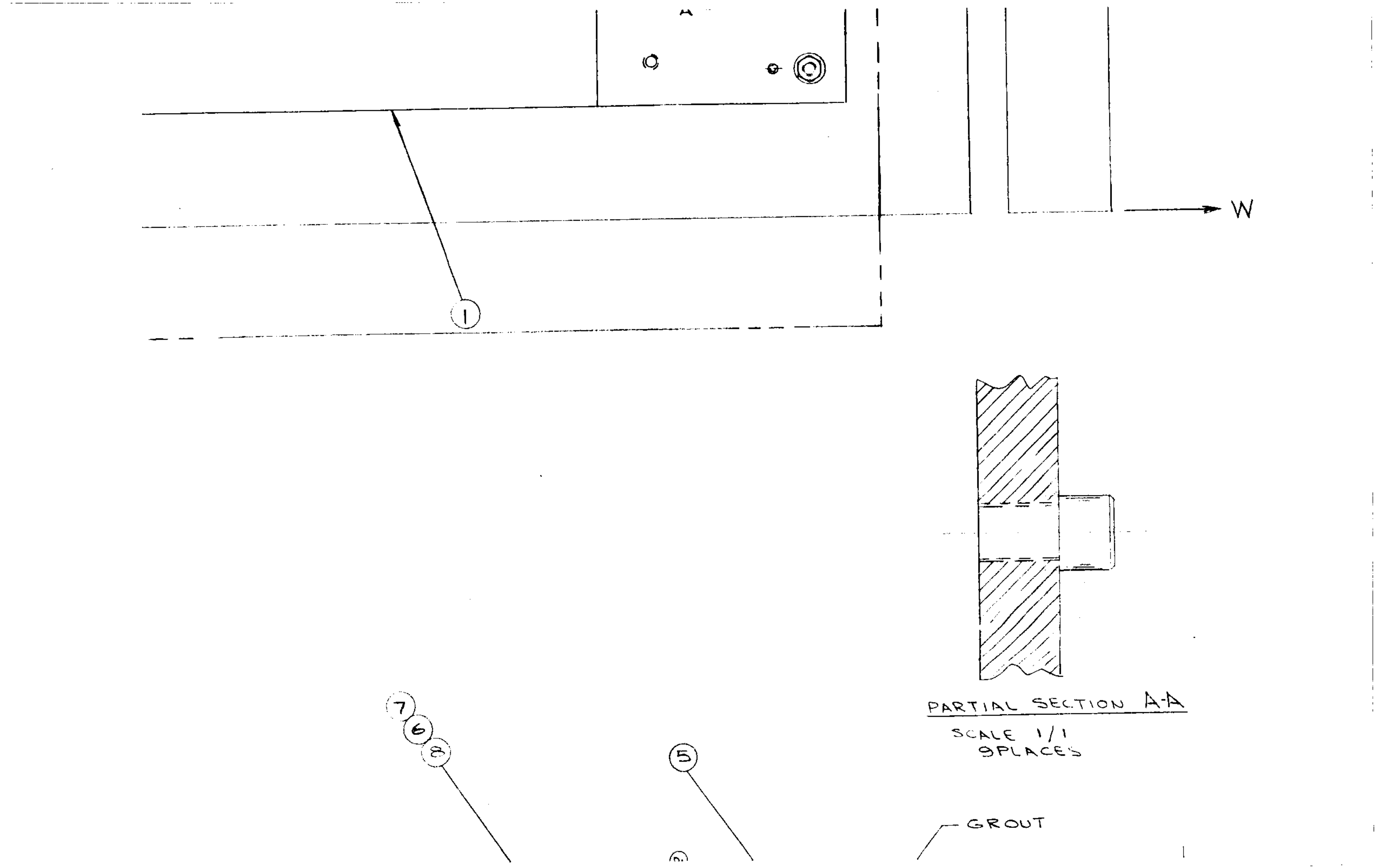
G

F

E

D


E
6
ANCHOR BOLT TEMPLATE
DWG Nº 563-1194
N
G
F
E
D

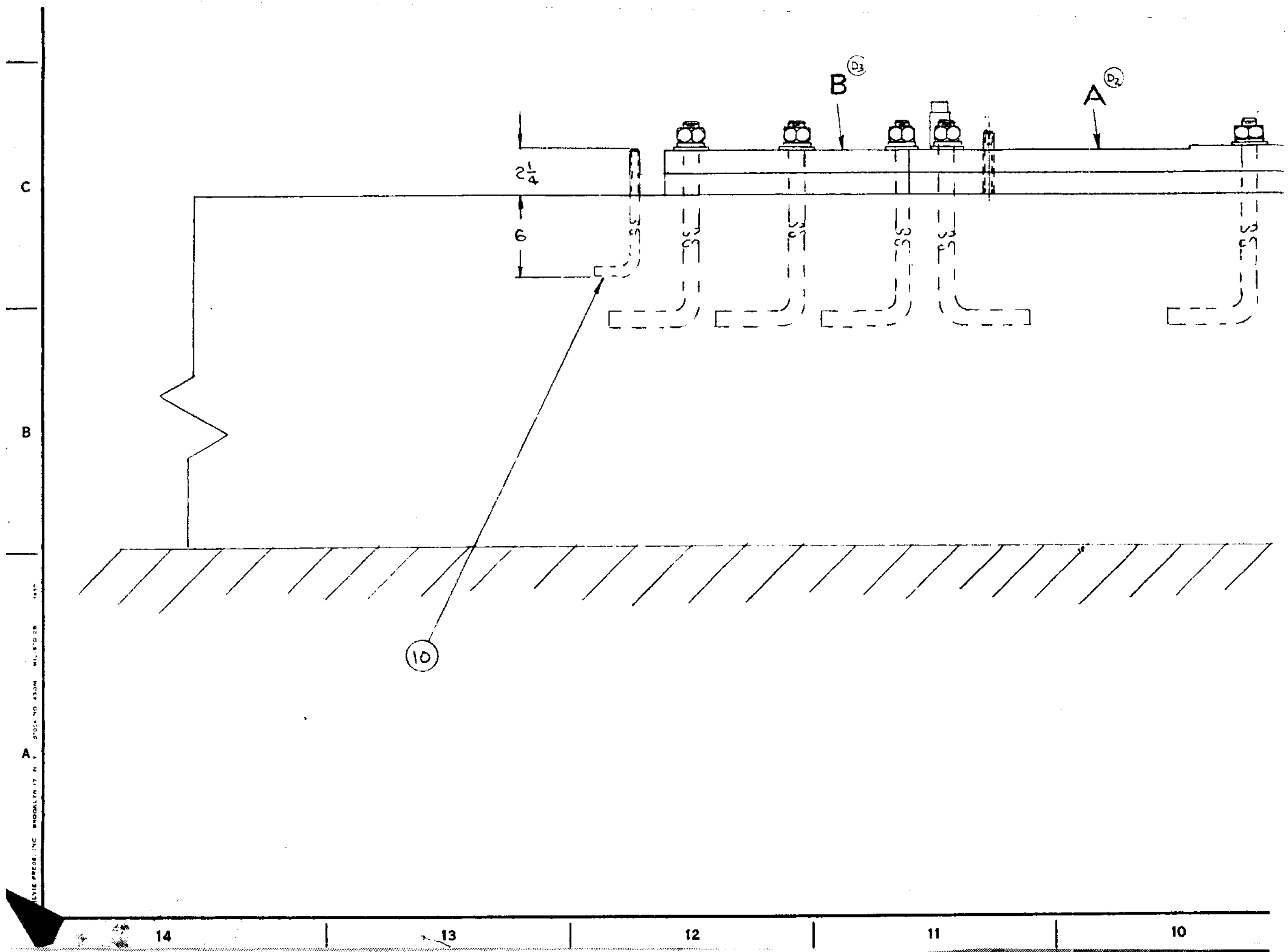

W
1
7
6
8
5
PARTIAL SECTION A-A
SCALE 1/1
9PLACES
GROUT

G

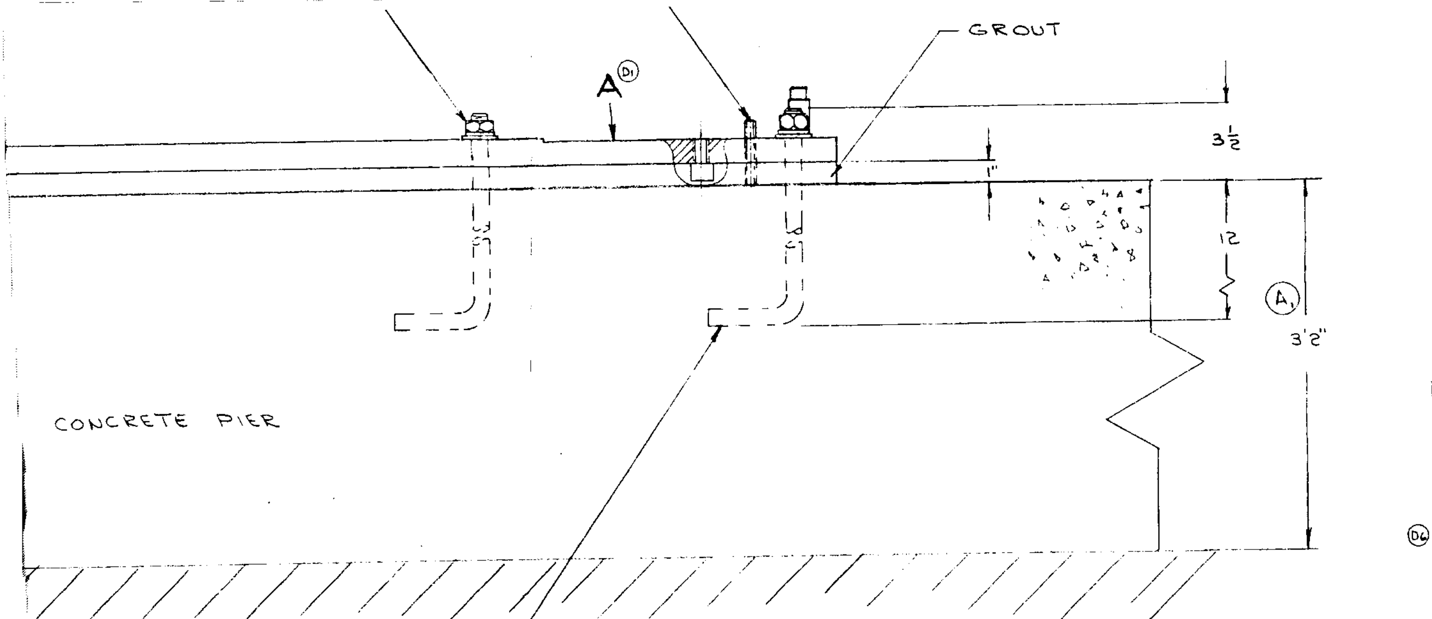
F

E

D



B (D3)
A (D2)
2 1/4
6
10
C
B
A
14
13
12
11
10



SEE NOTE 1

NOTES —

1. MATERIALS ARE LISTED FOR REFERENCE PURPOSES ONLY. SEE 563-0010 AND OTHER ASSEMBLIES FOR PARTS CALLOUTS.

(D5) 2. SURFACES (A) TO BE LEVELED AT ASS'Y TO WITHIN 2 MIN.

(D4) 3. SURFACE (B) TO BE LEVELED AT ASS'Y TO WITHIN 5 MIN.

NEXT ASSEMBLY	QUANTI

9 8 7 6 5 4

DRAWING NO. 563-0015

D
REV. LTR.

ITEM NO.	PART NUMBER	DESCRIPTION	QTY REQD	MATERIAL	SPEC.	UNIT WT.	CODE IDENT
11							
10	REFERENCE	ANCHOR BOLT 3/8-16 UNC		CRES			
9	REFERENCE	ANCHOR BOLT 3/4-10 UNC		CRES			
8		NUT, HEX 3/4-10 UNC	9				
7	MS35338-89	WASHER, LOCK	9				
6	MS15795-322	WASHER FLAT	9				
5		SCREW SOCKET SET SCR 1/2-20 UNF	7				
4	MS35461-23	SCREW SOCKET HD, CAP	18				
3							
2	563-0008	BASE ASSY, PRISM	1				
1	563-0007	BASE ASSY., THEODOLITE	1				

LIST OF MATERIALS

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
FRACTIONS ± 1/16 DECIMALS (2 PLACES) ± — (3 PLACES) ± — ANGLES ± —
SHARP CORNERS TO BE BROKEN TO .005 MAX. RAD.
ALL DIAMETERS ON SAME AXIS, CONCENTRIC WITHIN .006 T.I.R.
ALL √ SURFACES TO BE √
ALL DIMENSIONS AND TOLERANCES APPLY BEFORE FINISH TREATMENT.
MATERIAL —
FINISH —

ORIGINAL DATE OF DRAWING 7-17-62
DRAFTSMAN A AVANZATO
CHECKER B R
APPROVED
APPROVED
APPROVED W. Kokot
DES. APPROVAL
STDS. APPROVAL

ELECTRO-OPTICAL DIVISION
Perkin-Elmer Corporation
NORWALK, CONNECTICUT

BASE PLATE INSTALLATION
SATURN THEODOLITE

CODE IDENT NO.		
46555	E	563-0015
SCALE 1/4	WT	SHEET